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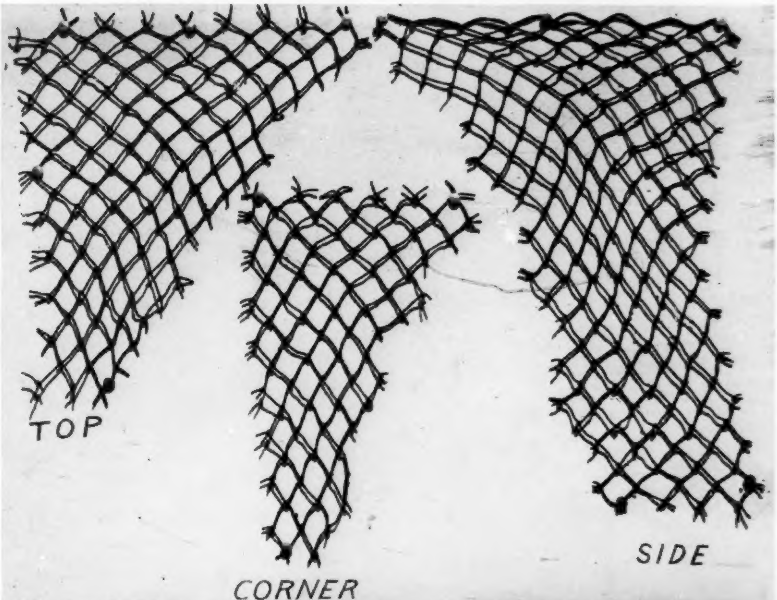

Shaping and Assembling Webbing

Marine Fisheries REVIEW

On the cover: Trawlnet tapers.
See the articles on pages 26 and 42.

Oct.-Nov.-Dec. 1983, 45 (10-11-12)

Articles

Departments

U.S. DEPARTMENT OF COMMERCE

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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National Marine Fisheries Service

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Ichthyoplankton and Fish Recruitment Studies in Large Marine Ecosystems

KENNETH SHERMAN, REUBEN LASKER, WILLIAM RICHARDS, and ARTHUR W. KENDALL, Jr.

ABSTRACT—Within the Fishery Management Zone of the United States, seven Large Marine Ecosystems (LME's)—Insular Pacific, Eastern Bering Sea, Gulf of Alaska, California Current, Gulf of Mexico, Southeast Atlantic Shelf, and Northeast Atlantic Shelf—support multi-billion-dollar fisheries, operating at different trophic levels. The LME's are characterized by unique bathymetry, hydrography, productivity, and population structure. To improve abundance forecasts of recruitment success of incoming year classes, two assessment strategies are used by NMFS in the LME's: 1) Fisheries independent surveys of fish eggs and larvae on mesoscale grids of 20-100 km at frequencies of two to twelve times a year to obtain estimates of the size of the spawning adult stocks, and 2) other studies within the mesoscale survey matrix aimed at discovering the processes controlling the annual recruitment success of new year classes. Processes under investigation include growth and mortality of eggs and larvae under variable density-dependent predator-prey interactions and density-independent influences of changes in circulation, water-column structure, biological production, and pollution. The sampling designs of the multispecies ichthyoplankton surveys in the LME's provide measures of spatial and temporal variability within acceptable confidence limits for estimating changes in abundance levels of spawning stock sizes off the northeast coast and in the California Current areas.

Introduction

Resource assessment studies of the National Marine Fisheries Service (NMFS) were expanded significantly during the middle 1970's to support the conservation and management of marine fishery resources within the U.S. Fishery Management Zone (FMZ) established by Congress in 1976 (Fig. 1). This law extended U.S. jurisdiction to a 322 km (200-mile) wide strip of ocean off all the U.S. coasts (over 3.5 million km^2).

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In this paper we provide an overview of the research strategies and new studies implemented by NMFS to overcome resource assessment problems posed by the large-scale temporal and spatial biological and environmental changes influencing the abundance levels of U.S. fishery resources within the FMZ. The new studies are part of an NMFS-NOAA initiative known as the Marine Resources Monitoring Assessment and Prediction (MARMAP) program.

The MARMAP program was built around a matrix of existing NMFS fishery resource assessment activities

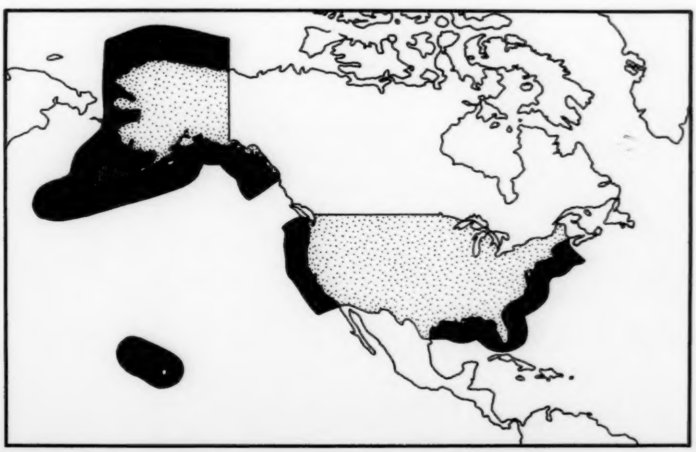


Figure 1. — The 3.5 million km^2 area of the U.S. Fishery Management Zone.

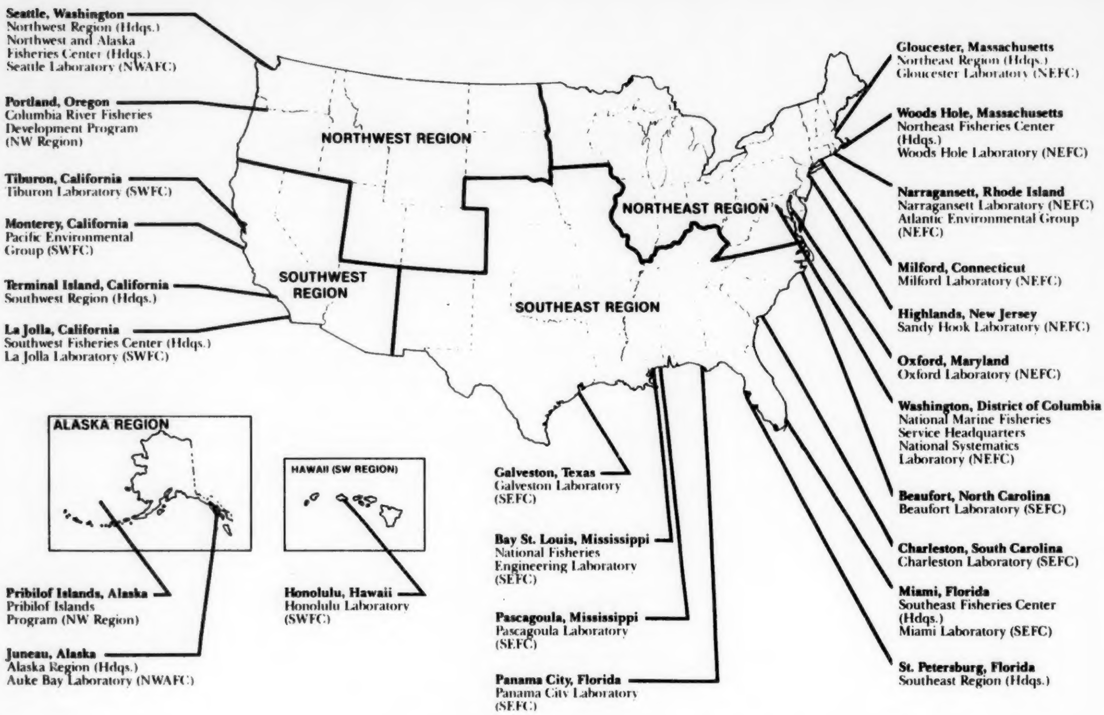


Figure 2. —The four fisheries centers and associated laboratories of the National Marine Fisheries Service, and the five regional headquarters and related offices.

including studies dealing with the analyses of catch statistics, the results of fishery surveys (pelagic, demersal, ichthyoplankton), fisheries oceanography, and fisheries engineering. A description of the early development of MARMAP program elements is given in a series of planning documents prepared by NMFS with the assistance of the Ocean Systems Division of TRW Company[1] (TRW Systems Group, 1973a,b, 1974.)

The coordination and integration of investigational components of MARMAP are major research activities of the four NMFS fisheries centers (Fig. 2). The Northwest and Alaska Fisheries Center, Seattle, Wash., is responsible for studying resources in the Gulf of Alaska, eastern Bering Sea, and off the coasts of Washington and Oregon. The Southwest Fisheries Center, La Jolla, Calif., has responsibility for the studies of the living resources of the California Current, Hawaii, and the Pacific Trust Territories. The Southeast Fisheries Center, Miami, Fla., assesses the resources from North Carolina to the Florida Keys, and in the Gulf of Mexico and Caribbean. The Northeast Fisheries Center, Woods Hole, Mass., studies the resources on the continental shelf from the Gulf of Maine to Cape Hatteras. The energetically related biological communities, bathymetry, hydrography, circulation, and productivity within each of these regions comprise coherent ecological systems encompassing broad geographic areas designated as Large Marine Ecosystems (LME's).

The fishery resources within the LME's are subject to management by Regional Fishery Management Councils, and management plans must ensure optimal sustained yields based on ecological, economic, and social considerations. The ecological decisions are based on the best scientific information available. Each fisheries center conducts ichthyoplankton studies as an important part of the overall MARMAP assessment to support the councils in developing management and conservation plans for regional fishery resources.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Fisheries Studies in Large Marine Ecosystems

From the turn of the century through the middle 1970's, fisheries studies were mainly focused on the yields of single species. This was not due to any lack of awareness of the interaction and interdependence of species, but rather to budget constraints on fisheries research institutions. However, from a fisheries management point of view, the best and most sought data follow an accurate prediction of future stock sizes and of the effect of different levels of fishing or environmental perturbation on the continued production of economically viable resource populations.

At present, NMFS under MARMAP has a more holistic approach to fishery assessment studies, with a focus on whole ecosystems and the multispecies interactions at different trophic levels that influence the annual production of fish populations. There are no shortcuts to obtain the comprehensive population and environmental information required to improve forecasts of fish abundance within the FMZ. A balanced approach is being implemented by NMFS that allows for:

1) A time-series of measurements in the form of standardized multispecies resource assessment and hydrographic surveys,

2) a systematic collection of fish-catch data, and

3) process-oriented studies dealing with biological and environmental linkages among key ecosystem components important to fish production in the sea.

Studies of single species alone do not provide sufficient data for effective management of multispecies fisheries operating at different trophic levels. While it is important for management purposes to continue these studies, they are now being pursued by NMFS within a broader matrix that measures interactions leading to changing abundance levels among the key species in the ecosystem. Single-species yield models have been augmented with multispecies models that are ecologically sensitive (Regier and Henderson, 1973; Parrish, 1975; Andersen and Ursin, 1977; Sheldon et al., 1977; Beddington et al., 1979; Grosslein et al., 1980; Laevastu and Favorite, 1981; Laevastu and Larkins, 1981; Mann, 1982; Sissenwine et al., In press; Jones[2]; Laevastu and Favorite[3]; Sherman et al.[4]).

These models deal with multispecies fishery interactions at different trophic levels. They are important approximations of the consequences of predator-prey dynamics, based on fishery-imposed selective mortality, and hold promise for providing a basis for the management of marine ecosystems. For example, possible species replacements of heavily fished mackerel and herring stocks with smaller, fast-growing, economically less desirable species have been reported for the North Sea based on a multispecies predator-prey model simulation supported by yield data (Andersen and Ursin, 1978) (Fig. 3). A review of the fish-stock replacement concept can be found in Daan (1980). However, if ecosystem models are to assume an appropriate role in the management of fishery resources, it will be necessary to overcome present deficiencies in:

1) Identifying the linkages between primary, secondary, and fish production;

2) quantifying predator-prey dynamics; and

3) understanding the relationship between stock size and recruitment.

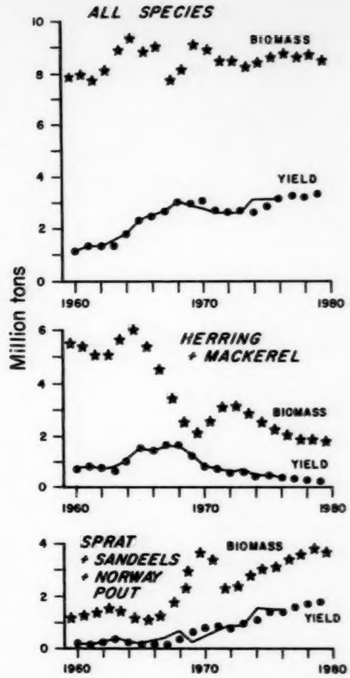


Figure 3. — Estimated changes in the biomass of fishes in the North Sea, 1960-76, with simulated yield and biomass projections to 1980. The 1.0 million metric ton decline in mackerel and herring stocks from 1968-76 from excessive fishing mortality is thought to be compensated for in the North Sea Ecosystem by replacement with small, fast-growing, opportunistic species (i.e., sprat, sand lance, Norway pout). Source: Andersen and Ursin (1977).

Ichthyoplankton Studies in LME's

The role played by ichthyoplankton in the transfer of energy in the food web is critical to an understanding of the density-independent (environmental) and density-dependent (competitor, predator) controls over the recruitment of new year classes in LME's. The six LME's for which significant NMFS resources have been dedicated to ichthyoplankton investigations include the Eastern Bering Sea, Gulf of Alaska, Washington-Oregon Coast, California Current, Gulf of Mexico, and the Northeast Continental Shelf (Fig. 4). Each is characterized by unique bathymetry, hydrography, productivity,

[2]Jones, R. 1976. An energy budget for North Sea fish species and its application for fish management. ICES C.M.1976/F:36.

[3]Laevastu, T., and F. Favorite. 1978. Numerical evaluation of marine ecosystems. Part I. Deterministic bulk biomass model (BBM). NMFS Northwest and Alaska Fisheries Center, Seattle, Wash. Processed Rep., 22 p.

[4]Sherman, K., E. Cohen, M. Sissenwine, M. Grosslein, R. Langton, and J. Green. 1978. Food requirements of fish stocks of the Gulf of Maine, Georges Bank, and adjacent waters. ICES C.M.1978/Gen:8 (Symp.).

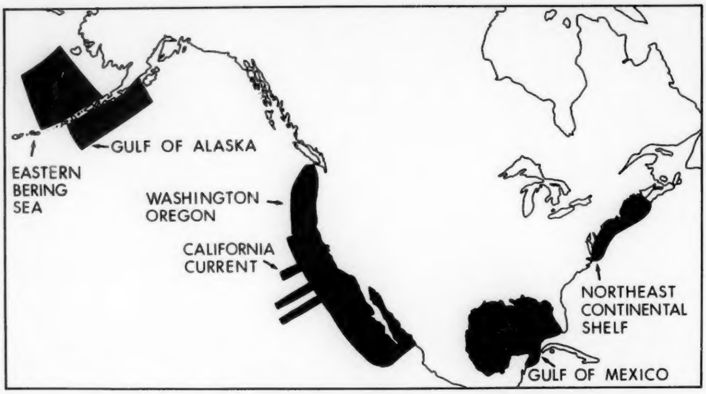


Figure 4. — The six Large Marine Ecosystems where NMFS ichthyoplankton assessment studies are underway.

and population structure. Collectively, they yield approximately 5 percent of the global fish catch, and support a multibillion-dollar annual fish catching, processing, and marketing industry.

In the LME's, two assessment strategies — ichthyoplankton surveys and trawl surveys — are used by NMFS to improve abundance forecasts of recruitment success of incoming year classes. Fisheries-independent surveys of fish eggs and larvae are conducted on mesoscale grids of 20-100 km at frequencies of two to twelve times a year to estimate the size of the spawning adult stocks. Ichthyoplankton surveys represent the most effective sampling strategy available for measuring abundance levels of all fish species inhabiting the LME's. The CalCOFI (California Cooperative Oceanic Fisheries Investigations) studies pioneered by Ahlstrom (1954) attest to the tractability of measuring population-level changes in the ichthyoplankton of the California Current system. The CalCOFI prototype ichthyoplankton survey was used as the standard approach in MARMAP and adapted for use in the LME's under investigation by NMFS. Ichthyoplankton surveys have only recently been implemented in the Gulf of Mexico, eastern Bering Sea, Gulf of Alaska, and off the Washington-Oregon coast by NMFS. Assessments of spawning biomass are an integral part of fish stock assessments in the California Current region and off the northeast coast.

The eggs and larvae of nearly all marine species in an LME can be quantitatively sampled with a single device — the plankton net. The early developmental stages are all vulnerable to the paired 60 cm bongo nets used on NMFS surveys (Posgay and Marak, 1981). Trawl surveys employing net systems, and in some areas acoustic signals and net systems, (e.g., for juveniles and adults of demersal and pelagic species) are more selective samplers. The sampling designs of the multispecies ichthyoplankton surveys within the LME's provide measures of spatial and temporal variability that are within acceptable confidence limits for estimating changes in abundance levels of parental spawning biomass in the California Current and off the northeast coast (Stauffer and Charter, 1982; Pennington and Berrien[5]). To obtain samples of ichthyoplankton used in spawning biomass estimates, the sampling is designed to encompass the temporal and spatial extent of spawning using a systematic grid of stations. A detailed description of the methods used by NMFS for multispecies ichthyoplankton sampling is given in Smith and Richardson (1977).

Within the mesoscale (20-100 km) multispecies ichthyoplankton time-series surveys (bimonthly to semi-annual), studies of the recruitment process are nested for target species on a finer horizontal and vertical scale (Lasker, 1981a; Lough and Laurence[6]) aimed at discovering the processes controlling annual recruitment success of new year classes. Processes under investigation include growth and mortality of eggs and larvae under variable density-dependent predator-prey interactions and density-independent influences of changes in circulation, water-column structure, biological production, and pollution. Among the target species of recruitment studies are walleye pollock, *Theragra chalcogramma*; Pacific king crab, *Paralithodes* spp.; Pacific sardine, *Sardinops sagax*; Pacific anchovy, *Engraulis mordax*; Atlantic mackerel, *Scomber scombrus*; Pacific salmon, *Oncorhynchus* spp.; striped bass, *Morone saxatilis*; Pacific hake, *Merluccius productus*; silver hake, *Merluccius bilinearis*; Atlantic menhaden, *Brevoortia tyrannus*; Gulf shrimp, *Penaeus* spp.; bluefin tuna, *Thunnus thynnus*; spot, *Leiostomus xanthurus*; Atlantic croaker, *Micropogonias undulatus*; Atlantic cod, *Gadus morhua*; and haddock, *Melanogrammus aeglefinus*.

Southeast Fisheries Center

Initiation of Gulf of Mexico Ichthyoplankton Surveys

The ichthyoplankton programs of the Southeast Fisheries Center, under the direction of William Richards, have included pioneering surveys of the ichthyoplankton populations of the

[5]Pennington, M., and P. Berrien. 1982. Measuring the effect of the variability of egg densities over space and time on egg abundance estimates. *In* Report of the Working Group on Larval Fish Ecology, Lowestoft, England 3-6 July 1981, p. 127-141. ICES C.M.1982/L:3.

[6]Lough, R. G., and G. C. Laurence. 1982. Larval haddock and cod survival studies on Georges Bank. *In* Report of the Working Group on Larval Fish Ecology, Lowestoft, England 3-6 July 1981, p. 103-119. ICES C.M.1982/L:3.

Gulf of Mexico. From 1977 through 1982, the first comprehensive surveys were conducted over the entire region, including a total of 500 stations and 1,500 MARMAP-type bongo and neuston samples. Station locations are shown in Figure 5. Preliminary results are given in a report by Richards et al.[7] In addition to ichthyoplankton tows, the 1978-81 time-series included water-column measurements of temperature, salinity, nutrients, chlorophyll, and light penetration.

Preliminary analysis of species-abundance relationships demonstrated significant differences in rank order of abundance of the 20 most numerous families among the northeast, southeast, northwest, and southwest quadrants of the Gulf of Mexico (Table 1). A total of 137 genera and species in 91 families were identified from the samples. Mesopelagic families including the Myctophidae and Gonostomatidae were the predominate ichthyoplankton groups in the collections followed by the third- and fourth-ranking Bregmacerotidae, and the Scombridae (Potthoff et al., 1981). These analyses were performed on the 1978 time-series. Other samples are presently being sorted and the larvae identified to the family level by the Plankton Sorting and Identification Center in Szczecin, Poland (Sherman and Ejsymont, 1976).

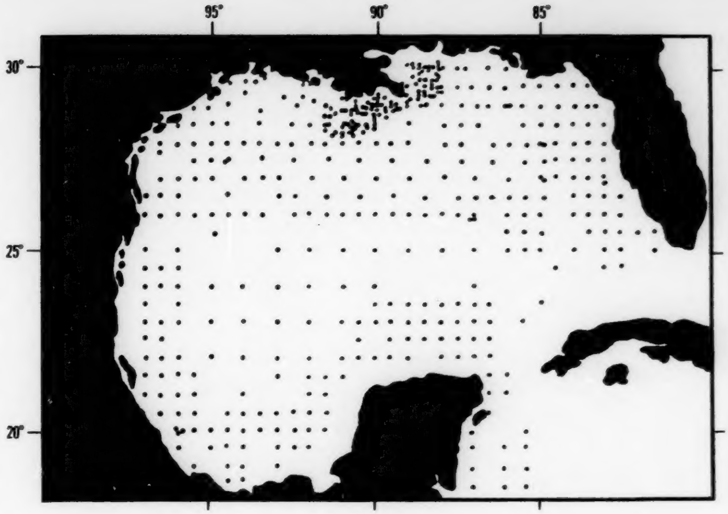


Figure 5. — Station pattern of the Gulf of Mexico ichthyoplankton surveys, 1982.

Table 1. — Rank order of the 21 most abundant families, *Oregon II* Cruise 87, 1978 overall and by quadrant in the Gulf of Mexico.

Overall rank	Rank by quadrant			
	Northeast	Southeast	Northwest	Southwest
1. Myctophidae	Myctophidae	Myctophidae	Myctophidae	Myctophidae
2. Gonostomatidae	Gonostomatidae	Gonostomatidae	Gonostomatidae	Gonostomatidae
3. Bregmacerotidae	Scombridae	Bregmacerotidae	Bregmacerotidae	Apogonidae
4. Scombridae	Bregmacerotidae	Scaridae	Gobiidae	Bothidae
5. Paralepididae	Stromateidae	Bothidae	Clupeidae	Bregmacerotidae
6. Stromateidae	Paralepididae	Scrombridae	Stromateidae	Stromateidae
7. Gobiidae	Carangidae	Labridae	Paralepididae	Paralepididae
8. Bothidae	Bothidae	Gobiidae	Serranidae	Scombridae
9. Serranidae	Synodontidae	Tetraodontidae	Synodontidae	Gobiidae
10. Synodontidae	Scaridae	Gempylidae	Scombridae	Serranidae
11. Scaridae	Serranidae	Carangidae	Bothidae	Gempylidae
12. Clupeidae	Gempylidae	Ophidiidae	Engraulidae	Engraulidae
13. Apogonidae	Apogonidae	Scorpaenidae	Carangidae	Anguilliformes
14. Carangidae	Labridae	Synodontidae	Anguilliformes	Carangidae
15. Labridae	Gobiidae	Serranidae	Gempylidae	Labridae
16. Engraulidae	Anguilliformes	Stromateidae	Apogonidae	Scaridae
17. Gempylidae	Engraulidae	Apogonidae	Labridae	Scorpaenidae
18. Tetraodontidae	Scorpaenidae	Paralepididae	Scaridae	Synodontidae
19. Anguilliformes	Tetraodontidae	Anguilliformes	Ophidiidae	Tetraodontidae
20. Ophidiidae	Ophidiidae	Engraulidae	Tetraodontidae	Ophidiidae
21. Scorpaenidae	Clupeidae	Clupeidae	Scorpaenidae	Clupeidae

Ichthyoplankton Identification Studies

The waters studied by the SEFC contain a basically tropical fauna, characterized by a large number of species (estimated at 1,500). Ichthyoplankton samples from tropical waters are generally characterized by few specimens but a great many species in each sample. Consequently, a large amount of effort has gone into studies to develop methods of identification of larval fish and eggs. In the late 1960's and early 1970's, over 60 species were reared in the laboratory from which identification series were developed. Interestingly, the first laboratory rearing of tuna was accomplished by Edward Houde and William Richards (Houde and Richards, 1969). Identification of larval series of tropical fish includes studies on tuna (Potthoff and Richards, 1970; Richards and Dove, 1971; Potthoff, 1974, 1975; Richards and Potthoff, 1974a,b; and Potthoff et al., 1980), on billfish (Richards, 1974; Potthoff and Kelley, 1982), on clupeoids (Houde et al., 1974; Richards et

[7]Richards, W. J., M. F. McGowan, and J. A. Ortner. 1982. Summary of Gulf of Mexico ichthyoplankton research 1977-1982 with bluefin tuna population estimates and preliminary analyses of larval bluefin distribution and ichthyoplankton assemblages. NMFS Southeast Fisheries Center, Miami Laboratory, Ref. Doc.

al., 1974), and on reef fishes (Saksena and Richards, 1975; Richards and Saksena, 1980; Houde and Potthoff, 1976). In addition to these publications, taxonomic studies are continuing on reef fish and oceanic pelagic larvae.

Bluefin Tuna Assessments

One of the priority species targeted for fisheries-independent estimates of parent stock biomass is the bluefin tuna, *Thunnus thynnus*. Estimates of spawning stock sizes were derived from larval abundances in 1977, 1978, and 1981 (Table 2). These estimates were of the same order of magnitude as fishery-dependent estimates derived from virtual population analyses. Distributions of bluefin tuna larvae in the Gulf of Mexico are shown in Figure 6. Correlations between bluefin tuna larval abundance and surface temperature, latitude, and zooplankton displacement volumes provide evidence of nonrandom distribution of bluefin tuna larvae in the Gulf of Mexico. Further analyses of the relationship between bluefin tuna larvae and environmental parameters will provide additional information on the species' life history. The spatial and temporal distributions will be used as a basis for stratification of the ichthyoplankton sampling design to reduce the variance of the population size estimates.

Table 2. — Estimates of bluefin tuna larvae and spawning stock with 95 percent confidence limits from Gulf of Mexico ichthyoplankton surveys.

Item	1977	1978	1981
Total larvae times 10^{10}	256± 826	594± 461	338± 635
Spawning stock	302,206 ± 1,007,555	699,951 ± 622,959	398,892 ± 791,402
Stations	48	135	76
Stations with bluefin larvae	15	49	13
Actual catch of bluefin larvae	34	292	51
Maximum catch per tow	7	33	19
Stations with >10 larvae	0	7	1

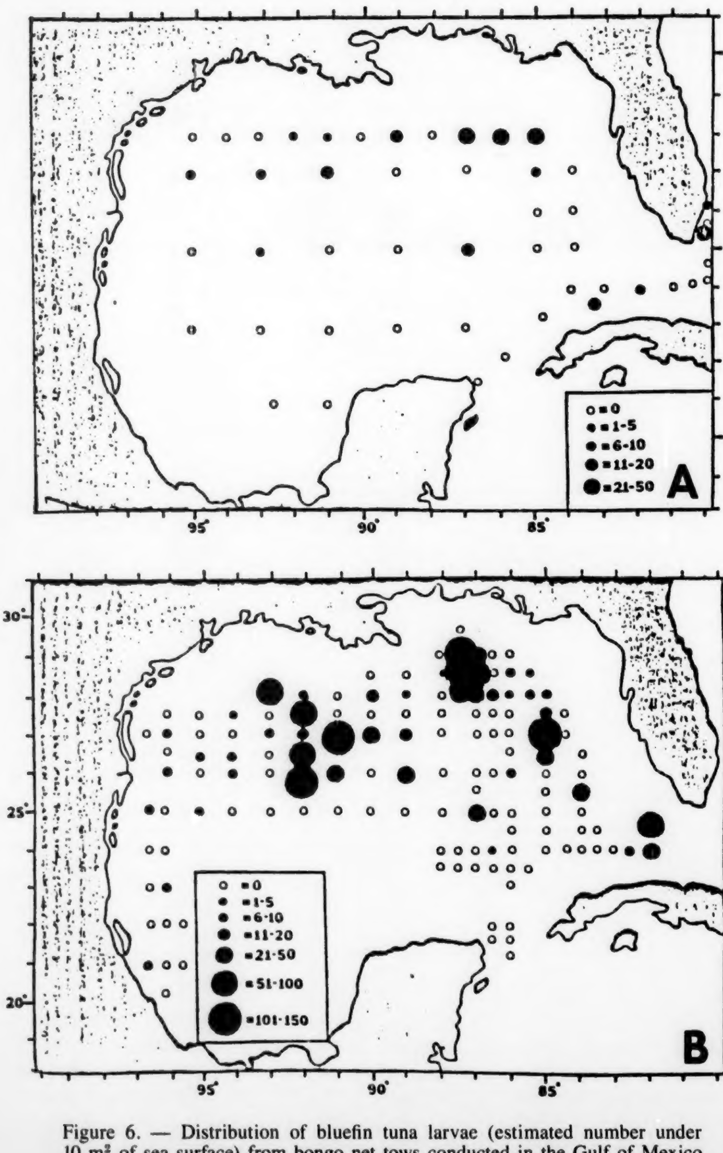


Figure 6. — Distribution of bluefin tuna larvae (estimated number under 10 m^2 of sea surface) from bongo net tows conducted in the Gulf of Mexico during (A) *Oregon II* 7705, 1977; (B) *Oregon II* 7803, 1978.

SEAMAP

The MARMAP studies of ichthyoplankton in the Gulf of Mexico have been designated as the SEAMAP (Southeast Area Monitoring Assessment and Prediction) program which is a joint Federal-State program coordinated through the Southeast Fisheries Center. During 1982, the first year of SEAMAP operations, ichthyoplankton sampling was expanded in the Gulf of Mexico in cooperation with scientists and ships from Mexico, Texas, Florida, Louisiana, and Mississippi. A listing of survey dates and sampling

Table 3. — Summary of ichthyoplankton cruises and types of samples collected in the Gulf of Mexico 1977-82.

Year	Cruise	Date	No. of completed stations	Environmental parameters										
				Bongo	Neuston	XBT	Surface temp.	Chlorophyll	Salinity	Secchi disk	Irradiance	Nutrients	^{14}C uptake	Gelbstoff
1977	*Oregon II*-77	29 Apr.-24 May	48	X	X		X							
1978	*Oregon II*-87	2 May-30 May	134	X	X	X	X	X						
1980	*Oregon II*-105	25 Feb.-27 Mar.	80	X	X	X	X	X			X	X	X	X
1981	*Oregon II*-117	1 May-26 May	102	X	X	X	X							
	Oregon II-120	15 Aug.-28 Aug.	45	X	X	X	X							
1982	*Oregon II*-126	15 Apr.-23 May	120	X	X	X	X	X	X	X				
	SEAMAP	June-July	491	X	X	X	X	X	X					

operations is given in Table 3. The Instituto Nacional de Pesca of Mexico employed three Mexican vessels to provide complete coverage of Mexican waters. Ichthyoplankton stations in the Gulf of Mexico were occupied by six research vessels. All the cruises were conducted in May, June, and July, the peak spawning time for many Gulf species. The ichthyoplankton samples from the surveys will be processed by the Polish Sorting Center. In 1983, the cooperative SEAMAP survey for ichthyoplankton has been repeated. In addition, a survey was conducted in the fall to obtain data on fall-spawning species.

The continued SEAMAP cooperation will allow for fisheries-independent estimates of stock size for all Gulf of Mexico species with pelagic eggs and larvae. The information will provide needed data on fishery resources, the nature of the early life history of these resources, and the mechanisms which affect growth and survival of early life history stages. Among the multispecies target resources to be investigated are tunas, mackerels, clupeoids, and reef fishes.

Ichthyoplankton and Pollution Stress

Under the direction of Ford Cross, the SEFC Beaufort Laboratory is conducting studies of the impact of pollutants in the Mississippi River plume on larval menhaden, croaker, and spot. Ichthyoplankton sampling is conducted from Cape San Blas, Fla., to Galveston, Tex., with a principal transect off the Mississippi River Delta. Collections are made with the standard bongo sampler and the multiple opening-closing net system (MOCNESS). Larvae are examined to determine age composition and prey composition and preference. Analyses of stable carbon ratios are conducted on components of the planktonic food web in the northern Gulf in conjunction with larval fish feeding studies to evaluate the importance of terrestrial organic matter as a source of carbon in their prey. In the transfer of carbon up the food chain, dinoflagellates and tintinnids have been established as the principal food source for first-feeding Gulf menhaden, *Brevoortia patronus*, larvae, whereas zooplankton is utilized as food by larval croaker and spot. Shipboard feeding experiments, using laboratory-reared larval menhaden and spot, are conducted to evaluate the effects of net collection procedures on the fate of soft-bodied prey, including tintinnids. In addition, laboratory studies are conducted on spot and Gulf menhaden to describe morphological indicators of starvation at different temperatures and growth rates.

Southwest Fisheries Center

Pioneering Studies

The NMFS Southwest Fisheries Center (SWFC) has an extensive larval fish program in its Coastal Fisheries Resources Division, led by Reuben Lasker. Studies on larval fish at the SWFC were begun by the late Elbert H. Ahlstrom who is acknowledged as a pioneer in larval fish identification and as the originator of egg and larvae surveys to determine the distribution and number of fish in the sea (Ahlstrom, 1954, 1959, 1965). The areal extent of the CalCOFI ichthyoplankton studies in the California Current ecosystem is shown in Figure 7. The ichthyoplankton abundance information obtained by Ahlstrom was instructive in documenting the failure of sardine recruitment in the California Current ecosystem and the increase in anchovy biomass, particularly in the absence of commercial fishery and associated catch statistics for the anchovy stocks during the 1950's and 1960's (Ahlstrom, 1966; Kramer and Smith, 1971) (Fig. 8). H. Geoffrey Moser continues ichthyoplankton work at the SWFC today and emphasizes the ecological interrelationships of all species of larval fish with their surrounding biota (Ahlstrom and Moser, 1981; Stephens and Moser, 1982; Butler et al., 1982).

Considerable effort has been expended over the past two years in organizing a symposium to honor Ahlstrom. The symposium, held 15-18 August 1983, was an attempt to summarize what is known of the systematics of early life histories of fishes and produce a compendium of egg and larval stages on a global scale. The published proceedings will extend the utility of ichthyoplankton studies in fishery assessments by providing a ready source for the identification of egg and larval stages for stock assessment purposes.

Physiological Ecology Studies

Physiological studies on larvae in the laboratory began with Reuben Lasker's work in the late 1950's. These investigations have now shifted to the field where laboratory data on larval fish are applied to ecological situations. This work attempts to provide insights into the relationship between the size of a fish stock and recruitment. Laboratory

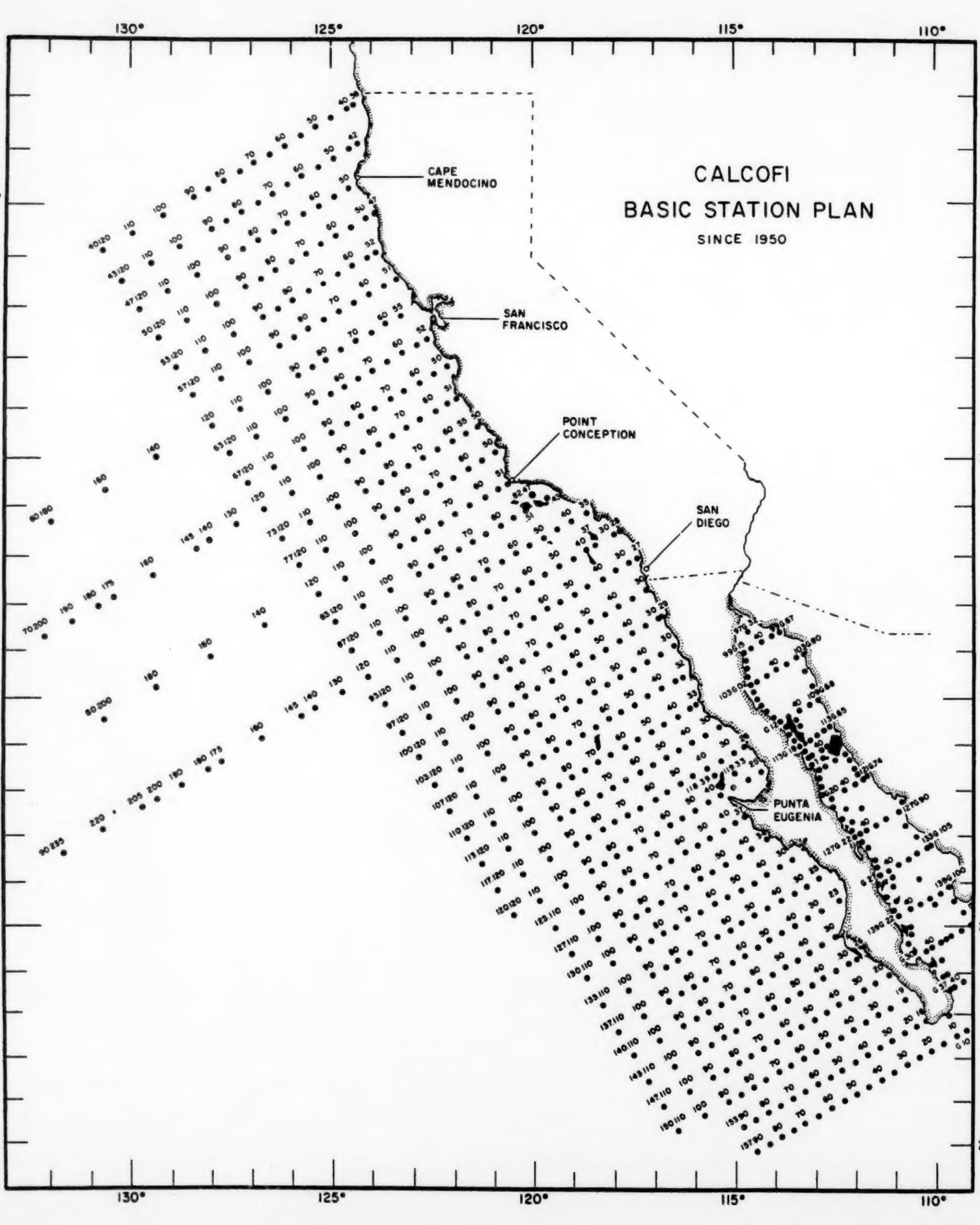


Figure 7. — CalCOFI area and ichthyoplankton station pattern since 1950.

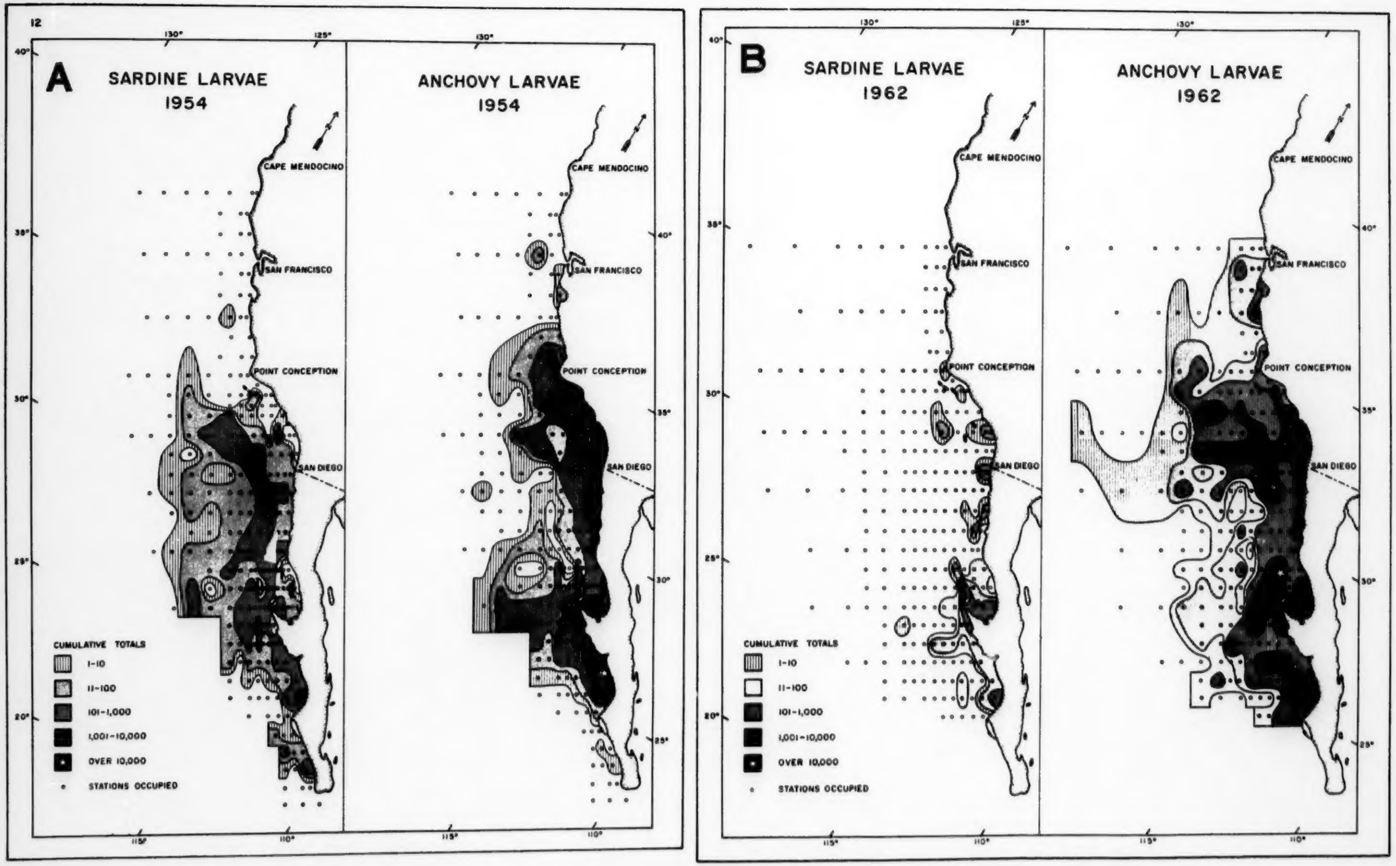
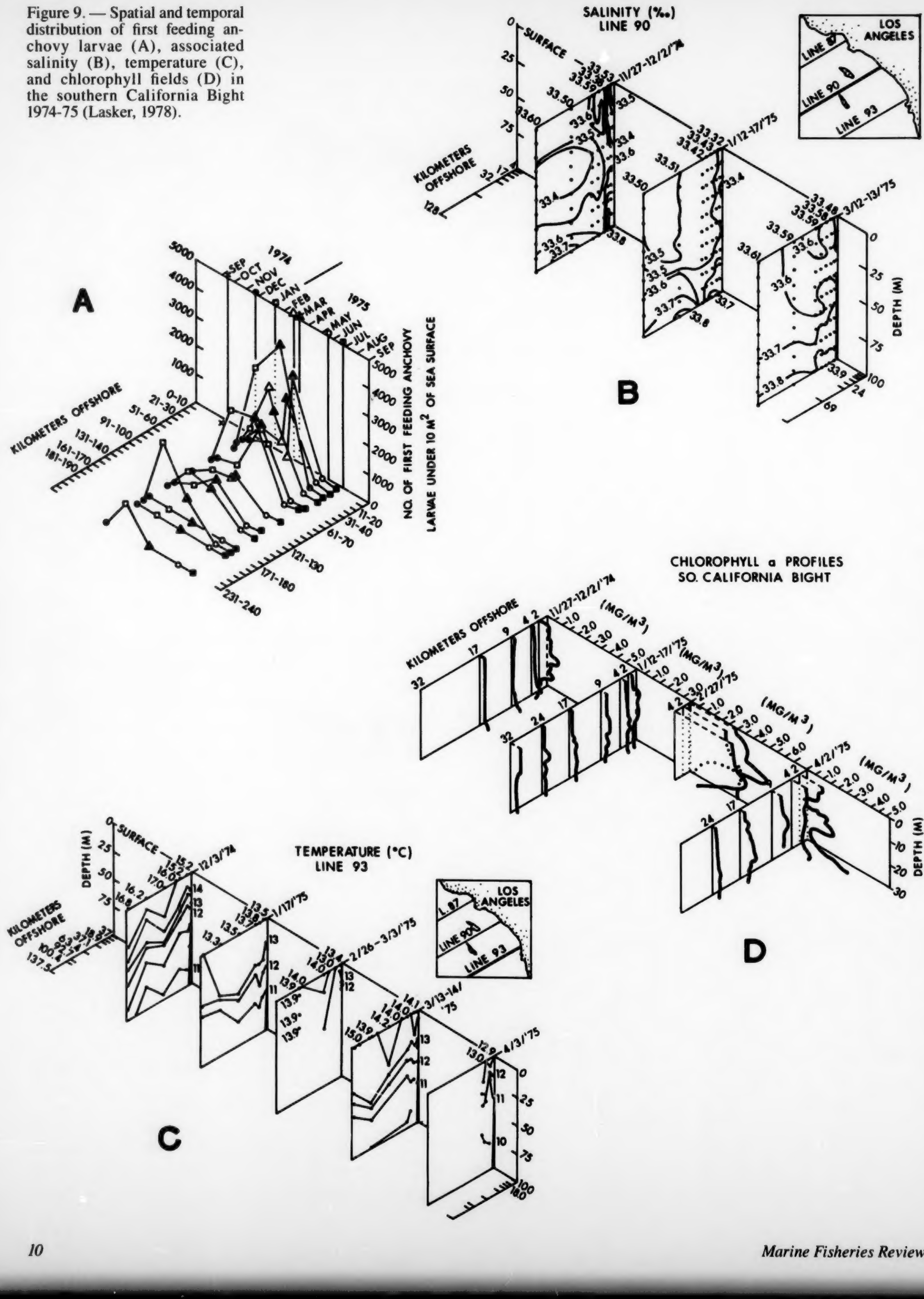


Figure 8. — Changes in the abundance of sardines and anchovies have been documented through the CalCOFI ichthyoplankton survey method. A = Relative abundance of sardine and anchovy larvae in 1954. B = The decline in sardines and population increase in anchovy based on CalCOFI surveys in 1962 (Ahlstrom, 1966).

Figure 9. — Spatial and temporal distribution of first feeding anchovy larvae (A), associated salinity (B), temperature (C), and chlorophyll fields (D) in the southern California Bight 1974-75 (Lasker, 1978).



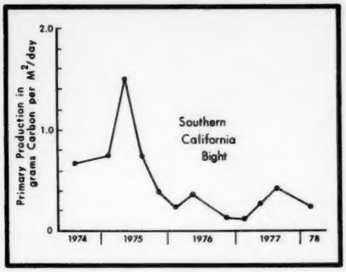


Figure 10. — Cumulative carbon production of the southern California Bight, 1974 through 1978 (Lasker, 1981).

and field data have been documented which support the hypothesis that stability of the ocean is an important factor in survival of anchovy year classes. The holistic ecosystem approach for investigating the oceanographic factors controlling year-class recruitment in relation to the growth and survival of anchovy larvae in the sea has been most productive. The CalCOFI sampling area encompasses the temporal and spatial extent of spawning, thereby allowing for a series of successful large-scale, at-sea experiments within the CalCOFI sampling grid on predator-prey relationships between anchovies and their prey field. Temperature, salinity, and chlorophyll profiles are used to identify oceanographic features that concentrate phytoplankton cells of the appropriate size and food quality for anchovy (Fig. 9). It is interesting to note that during the 5 years from 1974 through 1978, the greatest abundance of phytoplankton measured as the average production of mg C/m^2 d^{-1} was highest in 1975, the year of the poorest anchovy recruitment during the 5-year time-series of observation (Fig. 10).

Recruitment studies on the anchovy conducted by Lasker and his group have demonstrated the importance of moderate levels of stability in the California Current upwelling system to support the growth of the appropriate dinoflagellate prey, *Gymnodinium splendens*. Lasker (1975), with laboratory-spawned larvae of the northern anchovy, *Engraulis mordax*, in the sea at 13°-14°C, showed that they needed 30 40-50 μm (diameter) particles ml^{-1} to stimulate feeding and gut filling. This result was verified with laboratory experiments. Hunter (1977) has shown that the anchovy larvae need as many as 230 40 μm particles d^{-1}. Chlorophyll layers were discovered not far off the southern California coast which contained enough particles of *Gymnodinium splendens* to support the anchovy larvae (34-300 ml^{-1}, 40-50 μm in diameter). One such layer formed a patch about 100 km in length (Lasker, 1975).

Lasker (1981a) ranked anchovy year classes between 1962 and 1977. The 1975 year class was the lowest in rank in a calm year with high productivity, but *Gonyaulax polyedra* predominated. Scura and Jerde (1977) had shown that *G. polyedra* is not very nutritious and that anchovy larvae do not eat diatoms. The 1976 year class was the highest in rank in a calm year with low productivity, but *Gymnodinium splendens* predominated. From these studies it was concluded that larval anchovies probably use particles the size of *G. splendens* in the chlorophyll layers. Year-class strength of anchovies may depend upon the presence of *G. splendens* (as opposed to *Gonyaulax polyedra*) and upon the maintenance of the layers. Poor year classes may be the result of layer breakdown due to wind mixing or to the presence of *G. polyedra*.

Working closely with the Coastal Division, Richard Parrish, Andrew Bakun, Craig Nelson, and David Husby have applied newly devised oceanographic indexes to the study of this hypothesis and the concomitant larval drift theory of larval mortality (Bakun, 1973; Parrish, 1976; Bakun and Nelson, 1977; Parrish and MacCall, 1978; Bakun and Parrish, 1980, 1982; Parrish et al., 1981; Husby and Nelson, 1982; Brewer and Smith, 1982).

John R. Hunter began his larval fish studies by describing the behavior of anchovy larvae. While this work has continued on a number of species, he has in recent years shifted his emphasis to a study of the effect of alterations in the reproductive physiology of fishes on egg and larval survival (Hunter, 1972, 1981; Hunter and Kimbrell, 1980a,b; Hunter and Coyne, 1982).

In Hunter's Physiological Ecology group, Gail Theilacker and Charles O'Connell have established criteria for determining whether larvae in the sea are starving (Theilacker, 1978; O'Connell, 1980). Angeles Alvariño provides information on the distribution and abundance of invertebrate predators of larval fish (Alvariño, 1980, 1981). Robert Owen studies small-scale distribution of larvae and their food (Owen, 1980, 1981); and Richard Methot and Roger Hewitt have been making a careful analysis of the mortality of northern anchovy eggs and larvae in relation to the environment (Hewitt, 1981; Methot, 1981; Hewitt and Methot, 1982).

Paul E. Smith is responsible for studies of biomass estimation using egg and larval abundance as indicators of adult fish abundance (Smith, 1972). He provides the SWFC Coastal Division with the development and evaluation of survey systems, particularly the design and testing of new plankton nets, and is responsible for designing the surveys themselves.

CalCOFI Population Assessments

The Coastal Division also has responsibilities to the Pacific Fishery Management Council for biomass estimation of the northern anchovy and for monitoring the populations of a variety of other commercially valuable pelagic fish in the California Current ecosystem. Using the extensive background information on anchovy larvae and adults obtained over more than 20 years, a new "egg production method" for biomass estimation was devised by a Coastal Division team (Parker, 1980).

The egg production method produced by the SWFC for estimating the biomass of anchovy is used by the Pacific Fishery Management Council to manage the anchovy fishery. Besides its use off California, the method is being tried off Peru and South Africa. A number of other important techniques have been developed at the SWFC, e.g., spawning and rearing of many species of fishes with pelagic eggs and larvae (Lasker et

al., 1970), precise ageing of larvae by counting daily increments on larval otoliths (Brothers et al., 1976; Methot, 1981; Methot and Kramer, 1979), the resonance frequency acoustic technique for counting larvae and juveniles in the sea (Smith, 1972, 1978), histological and morphological measurements of larvae to indicate starvation (O'Connell, 1976, 1980, 1981), the use of ovarian follicle histology to determine frequency of spawning (Hunter and Macewicz, 1980), and others.

In the study of fish recruitment, the SWFC Coastal Division maintains over 25 years of egg, larva, and oceanographic data collected by CalCOFI. Many of the results appear in an annual peer-reviewed journal, the *CalCOFI Reports*. Processed data for the large area of the California Current ecosystem are published in the occasional publication, the *CalCOFI Atlas*, now in its thirtieth volume (Lynn et al., 1982). A short review and bibliography of the division's recent work are available in a book entitled "Marine Fish Larvae" and edited by R. Lasker (1981b).

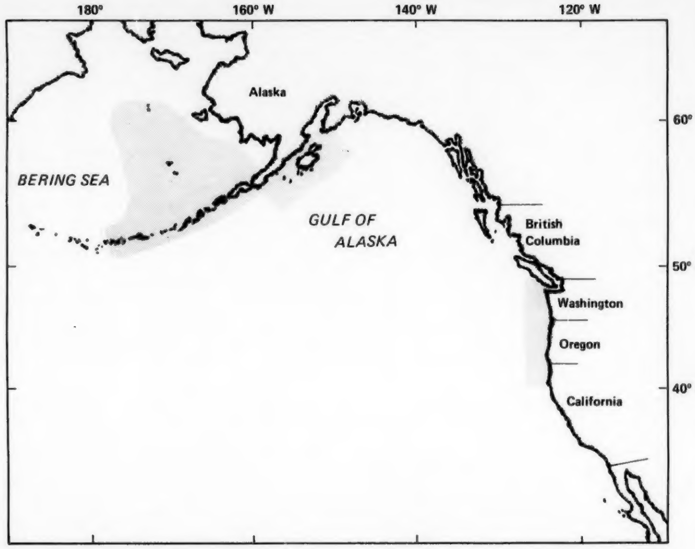


Figure 11. — Extent of ichthyoplankton studies of the Northwest and Alaska Fisheries Center in three LME's — Eastern Bering Sea, Gulf of Alaska, and off the Washington-Oregon Coast.

Ichthyoplankton and Pollution Stress

Studies of the impacts of pollution on the early life stages of marine fish are conducted at the SWFC Tiburon Laboratory under the direction of Janet Whipple. The target species in the study is the striped bass, *Morone saxatilis*. The abundance of striped bass in the San Francisco Bay and Delta region has decreased in recent years. Concerned with the future of this popular sport fish, a joint study team of scientists from the Center's Tiburon Laboratory, the University of California at Davis and Santa Cruz, and the California Department of Fish and Game have been studying likely causes of the decline. Preliminary results of the team's effort indicate that chronic toxic chemical exposures affect every stage of the striped bass life cycle, including significant depression in viable egg production and concentration of petrogenic hydrocarbons at levels sufficient to cause mortalities of larvae and juveniles (Whipple et al., 1981; SWFC Monthly Report[8]).

Studies are underway at the Honolulu Laboratory of SWFC to develop methods for breeding and rearing tuna in captivity for eventual assessment of environmental impacts on larvae and juveniles.

Northwest and Alaska Fisheries Center

Areas of Interest

The Northwest and Alaska Fisheries Center is responsible for recruitment processes studies for fishery resources in three LME's: Eastern Bering Sea, Gulf of Alaska, and off the Washington-Oregon Coast (Fig. 11). Studies are carried out under the direction of Arthur Kendall. In each of these areas the level of background information on the fish stocks varies, as do the fisheries-related problems. Within the framework of understanding causes of variation in year-class strength of fishes, tractable problems are being resolved by building on a growing information base that is developing step-by-step (Kendall et al.[9]).

Identification Guide

Early life history studies are focused on providing sufficient taxonomic expertise to identify the eggs and larvae of the most important species. Descriptions have been prepared of the diagnostic characteristics used for identification of Pacific tomcod, *Microgadus proximus*; walleye pollock, *Theragra chalcogramma*; and Pacific cod, *Gadus macrocephalus* (Fig. 12). At present only about half the larvae collected can be identified to species. A major effort now underway is the preparation of a laboratory guide for identification of

[8]SWFC Monthly Report. 1982. Tiburon Laboratory. NMFS Southwest Fisheries Center, La Jolla, Calif., August 1982:22.

[9]Kendall, A. W., Jr., J. R. Dunn, and A. C. Matarese. 1980. Early life history of fishes studied to help explain variations in abundance. Resource Ecology and Fisheries Management Division of Northwest and Alaska Fisheries Center, Seattle, Wash. Monthly Rep. July 1980.

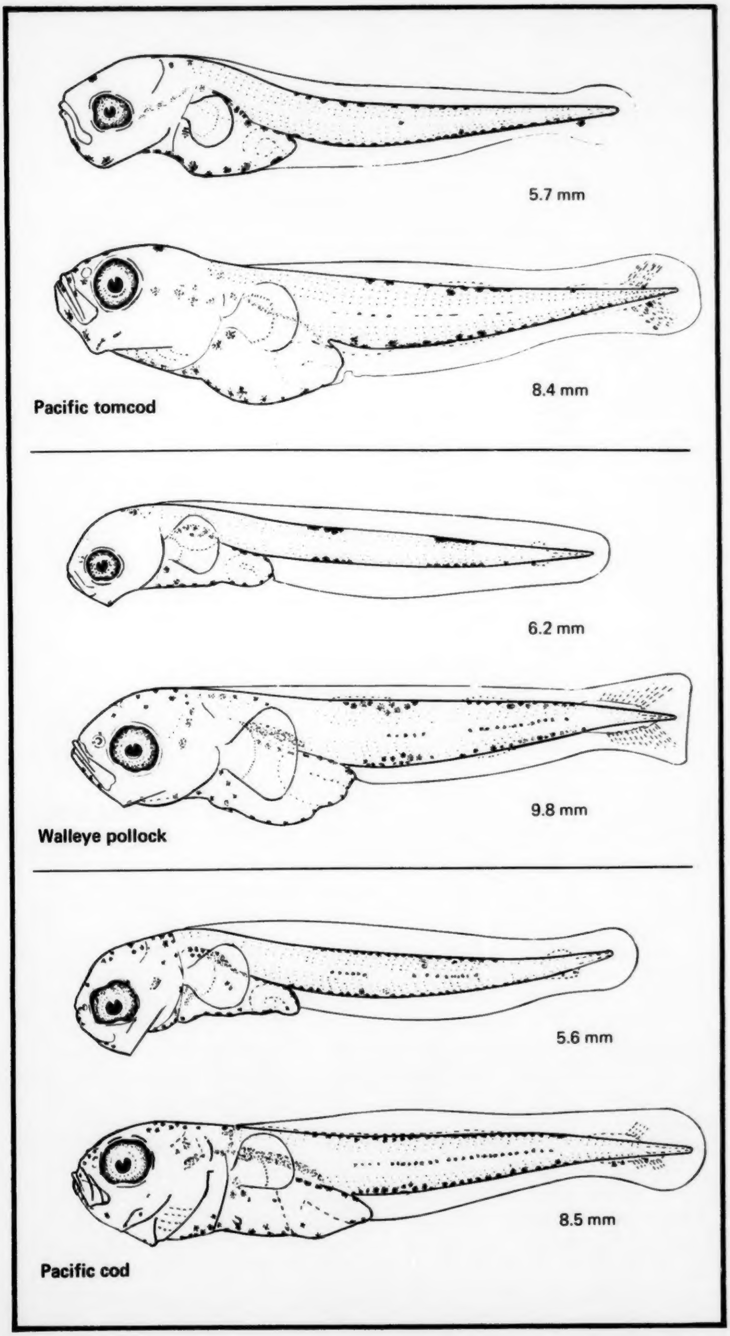


Figure 12. — Larval stages of three species of northeast Pacific gadids from a new taxonomic key in preparation by the staff of the NWAFC.

early life history stages of northeast Pacific fishes. Along with this effort is the initiation of a cooperative program on the identification of rockfish, *Sebastes* spp., larvae. Larvae of this commercially important genus are among the most abundant in the surveys in spring and summer, but cannot be identified to species. It will be necessary to conduct rearing experiments from identified adults to resolve the *Sebastes* taxonomic problem.

Eastern Bering Sea Ecosystem

In recent years ichthyoplankton studies in the Eastern Bering Sea ecosystem have been targeted on the eggs and larvae of walleye pollock. From these studies, information has been obtained on spawning times and places, vertical distribution, and growth patterns (Fig. 13). The National Science Foundation-sponsored Processes and Resources of the Bering Sea (PROBES) shelf program has augmented our knowledge of the ecology of developing walleye pollock eggs and larvae with results from plankton and physical oceanographic studies aimed at describing the processes involved in the initiation and maintenance of the spring phytoplankton-zooplankton bloom which provides the food base for larval and juvenile pollock. Future studies in the Eastern Bering Sea ecosystem will focus on two problems: 1) Acquiring sufficient information on the spatial and temporal distributions of newly-spawned pollock eggs and larvae and 2) the need to measure interannual variability of the key ecosystem components (e.g., light, advection, prey field, predation field) that influence the growth and survival of pollock.

Initial estimates of the size of the spawning biomass of pollock were made in spring 1977. These surveys, and others conducted by scientists of Japan and the U.S.S.R., indicated that walleye pollock spawning begins as early as mid-February and continues through June, and that their planktonic eggs in the eastern Bering Sea are found primarily south and east of the Pribilof Islands and north of Unimak Pass. Estimates of the total number of eggs in the water column were made for five

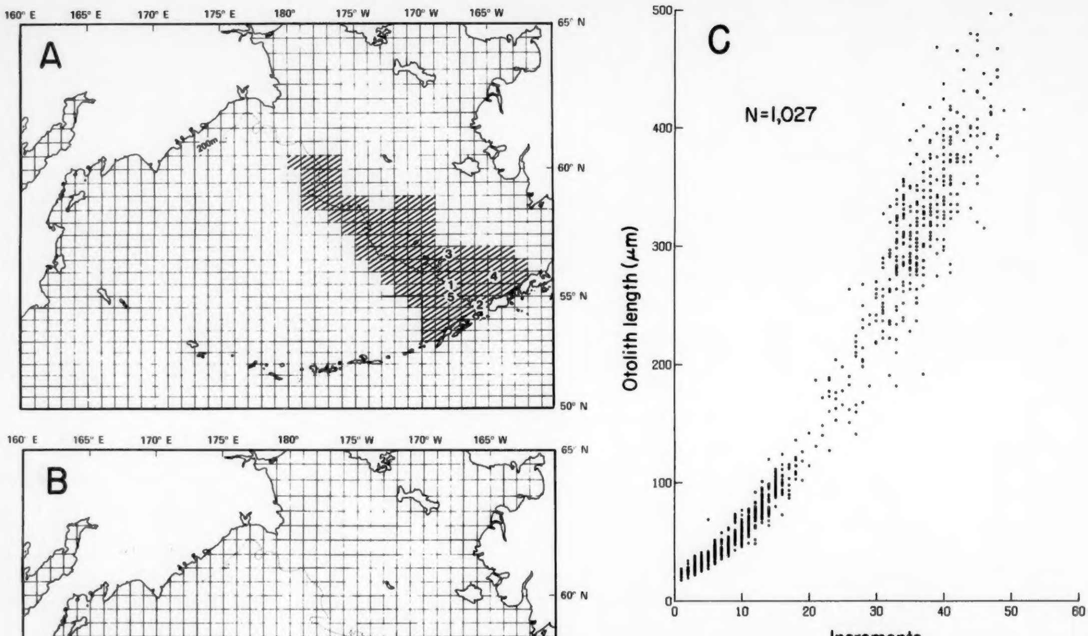


Figure 13. — Areas where walleye pollock eggs and larvae have been caught in plankton tows in the eastern Bering Sea. Shaded area of A is where pollock eggs have been caught; superimposed numbers are areas of maximum abundance in five different years. B shows numbers of stations in each area at which larvae have been caught in spring, and C is otolith length in micrometers plotted against the number of daily growth increments observed. Each point represents one larva.

time-periods from 16 April to 10 May 1977; the maximum estimate was 7.8×10^{12} eggs in the period 19-27 April.

In 1977 walleye pollock larvae appeared to be distributed to the west of the area where peak spawning occurred. This observed distribution, however, cannot be explained by circulation of water masses as presently understood. It may be caused by different survival rates in different areas. Modal lengths of walleye pollock larvae increased from 5.5 mm in mid-April to 8.3 mm in mid-May. Estimates were also made of abundance of larvae by time periods. The maximum estimated numbers of larvae (7.5×10^{12}) occurred during the same time-period as the highest egg abundance.

Comparisons of estimates of abundance of walleye pollock eggs and larvae during similar time-periods in 1976 and 1977 indicated that eggs were more abundant in 1976 than in 1977, but more larvae were present in 1977 — possibly indicating a change in spawning time. Comparisons of the spatial distribution of eggs and larvae in 1976 and 1977 suggested that the centers of abundance were also different in both years.

To investigate further these apparent temporal and spatial shifts in the distribution of walleye pollock eggs, additional sampling was conducted in the eastern Bering Sea in February and March 1978; June and July 1979; and mid-January to mid-February 1980. Although samples from the latter cruise have not been analyzed, the earlier surveys confirmed the presence of walleye pollock eggs as early as mid-February and as late as mid-June. Future research plans, directed toward early life history of the walleye pollock, include additional work to determine the time and area of spawning and the annual variation of larval abundance in the eastern Bering Sea.

King crab, *Paralithodes* spp., populations have varied in the eastern Bering Sea from about 5 million exploitable males in 1971 and 1981-82 to about 50 million in 1978-79 (and, perhaps, in 1964-65). While fishing may well have affected these fluctuations, independent estimates of portions of the stock not affected by fishing (females and juve-

niles not harvested) have shown similar fluctuations. Also, other crabs and shrimps with similar life histories have shown major variations in abundance independent of fishing. After hatching, larval crabs remain in the water column for about 6 weeks where they feed and molt into successive forms that eventually settle to the substrate to begin benthic life. During this period, they are subject to variations in transport, turbulence, temperature, food, predation, etc. As benthic animals, the juvenile crabs occupy nearshore shallow habitats and concentrate in large shoals or "pods" that may, at times, be vulnerable to mass mortality caused by predation, or by small-scale spatial-temporal anomalies in environmental conditions. At about 3-4 years of age, the crabs recruit to the offshore populations where they become closely associated with the adult life history categories.

Our approach to recruitment studies of king crab will be to build on the historic data base, and especially the results of the large recent efforts by OCSEAP (Outer Continental Shelf Environmental Assessment Program, BLM and NOAA) and by PROBES. The program will incorporate the talents of the NMFS, National Ocean Survey, Pacific Marine Environmental Laboratory of NOAA, and Northwest and Alaska Sea Grant institutions, and will include review of existing data sets, identification of critical factors, design of experiments in the laboratory and field, and development of analytic and prediction models. Recruitment studies will include surveys to establish an interannual time-series to follow survival of the successive life stages of individual year classes. These hypotheses will be tested: That larval survival is associated with the biological bloom that follows retreat of the ice front and/or that larval survival depends upon the thickness and stability of the mixed layer depth in April in the mid-shelf region. An experiment will be conducted in 1986 to follow the ice meltback of the eastern Bering Sea. The experiment will examine the role of the ice and its meltwater in establishing a "nursery layer" and its impact on crab survival.

Gulf of Alaska Ecosystem

In the Gulf of Alaska, the importance of Shelikof Strait is being evaluated as a principal spawning ground for walleye pollock stocks. Through time-series surveys of pollock eggs and larvae, estimates of pollock spawning biomass have been made. Their populations have shown fluctuations of within-year-class strength of from two to five times the mean number. Research to date indicates that the spawning and subsequent egg and larval drift follows a remarkably consistent pattern from year to year. For example, a single spawning concentration in Shelikof Strait near Kodiak Island contained 2.5 to 2.7 million metric tons of pollock in March 1983. The spawning is restricted in time (late March-early April) and localized geographically (in lower Shelikof Strait in an area 20×70 km). The eggs, and later the larvae, form a large patch that drifts with the prevailing current to the southwest along the Alaska Peninsula, mainly at depths between 20 and 50 m. Development time for the eggs is about 2 weeks; the larva start to feed in the first week after hatching and remain planktonic for about 6-8 weeks. The dominant transport feature of Shelikof Strait is the Kenai Current, which flows westward along the Alaskan coast from the vicinity of the Copper River to Unimak Pass. The two dominant mechanisms of current variability are freshwater runoff and wind stress. There are strong annual and interannual signals in the freshwater discharge, and these are correlated with fluctuations in transport.

Hydrographic data and satellite infrared (IR) observations show warm waters entering Shelikof Strait during March. The juxtaposition of these warm waters with cold, less saline water from Cook Inlet that flows over a rough topography and is influenced by strong local winds, can lead to intense mixing and upwelling. These intense mixings can be sustained by storms, and advected by the currents on time scales of weeks. These transport variations affect the distribution of the pollock eggs and larvae and probably alter their survival rates. The intense, localized nature of this early life-history pattern, in a relatively confined oceanographic setting, lends itself ideally to tractable recruitment experiments, with a high likelihood for prediction of year-class strength and understanding causes of its variability. To gain insight into mechanisms causing variation in recruitment and year-class strength, studies will be conducted on linkages among circulation, spawning, egg and larval growth, survival, and advection in the Gulf of Alaska ecosystem.

Samples from surveys conducted before 1981 have been used to describe the ichthyoplankton community in the vicinity of Kodiak Island (Kendall and Dunn, In prep.). These and later collections will also be used to map the distribution and abundance of walleye pollock in the Shelikof Strait region (Fig. 14). Surveys in this region have been conducted jointly with scientists and vessels of the Soviet Union and South Korea. Future studies will include: 1) Investigation of the factors influencing survival of planktonic early life history stages of fish in relation to recruitment of incoming year classes, and 2) evaluation of the use of early life stages for measuring sizes of parental spawning biomass.

Species of primary interest include: Walleye pollock, rockfishes, flatfishes, Pleuronectidae; greenlings, Hexagrammidae; and sculpins, Cottidae. The areas of primary interest include Shelikof Strait and the continental shelf off Kodiak Island. Specific projects on Gulf of Alaska early life history stages will include studies on: 1) Distribution and abundance of eggs and larvae of walleye pollock, 2) description of the ichthyoplankton community of the Kodiak area, 3) identification of species of *Sebastes* larvae, 4) annual changes in relative abundance of various species in relation to environment, and 5) laboratory guide for identification of eggs and larvae of fishes of the northeast Pacific Ocean.

Washington-Oregon Coastal Ecosystem

In 1980, a cooperative program was initiated with scientists from the TINRO Laboratory in the U.S.S.R. to determine the annual cycle of ichthyoplankton

occurrence off the Washington-Oregon coast (Fig. 15). Two surveys per year are conducted on Soviet vessels, sampling about 125 stations per survey. The surveys are conducted at different times of the year, so that after several years the complete cycle of fish egg and larval occurrence can be documented.

Standard MARMAP bongo samplers are deployed on each survey. These surveys will be the first large-scale ichthyoplankton surveys of the area to sample in all seasons. Following completion of the definition of peak spawning periods for the dominant species and/or species groups, specific unresolved problems concerning recruitment can be addressed. Species targeted for recruitment studies are: Sablefish, *Anoplopoma fimbria*; rockfish, *Sebastes* spp.; and flatfishes (*Limanda* sp., *Platichthys* sp., *Eopsetta* sp.). Results from these surveys will be compared with those of CalCOFI to the south, thereby linking the ichthyoplankton data base from off Baja California to Cape Flattery. A description of survey operations and preliminary results from the first two surveys are given by Kendall and Clark[10,11].

Using the CalCOFI data base, it has been possible to relate the seasonal patterns of distribution of larvae, juveniles, and adults of the Pacific hake, *Merluccius productus*, to spawning, feeding, and schooling areas in the California Current and Washington-Oregon coastal ecosystems (Bailey et al., 1982) (Fig. 16). In cooperation with Polish scientists, preliminary information has been obtained on Pacific hake predator-prey relationships (Table 4).

Table 4. — The percent by weight and region of food types in the diet of Pacific hake determined by Polish scientists[1] in summer 1979.

	Percent by region		
Food type	Eureka	Columbia	Vancouver
Euphausiids	94.2	94.0	85.6
Juvenile rockfish	1.0	1.6	
Pacific herring			
Adult			5.9
Juvenile			6.6
Osmerids		0.4	
Pacific hake	0.5		
Sablefish		2.0	0.1
Flatfish		0.4	
Squid		1.6	
Shrimp		1.6	
Other fish	3.2		1.7
Other invertebrates	0.4		0.1

[1]Jackowski, E. 1980. Biological characteristics of Pacific whiting from Polish surveys of the west coast of the U.S.A. and Canada in 1979. Unpubl. manuscr. presented at the U.S.-Poland bilateral meetings, 1980.

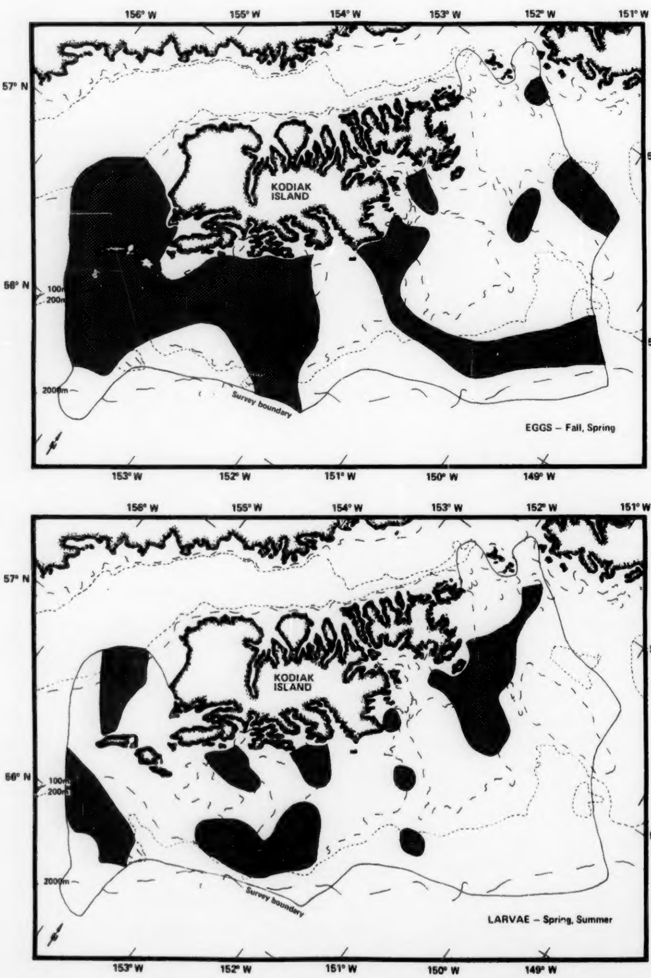


Figure 14. — Areas where walleye pollock eggs and larvae were caught in neuston and plankton tows off Kodiak Island, 1977-78. Eggs were caught in fall and spring; larvae were caught in spring and summer.

Pacific Salmon

The Pacific salmon group is usually second only to shrimp in ex-vessel value to U.S. fishermen ($438 million in 1981). This species group provided

[10]Kendall, A. W., Jr., and J. Clark. 1982. Ichthyoplankton off Washington, Oregon, and Northern California, April-May 1980. NMFS Northwest and Alaska Fisheries Center, Seattle, Wash. Proc. Rep. 82-11, 44 p.

[11]Kendall, A. W., Jr., and J. Clark. 1982. Ichthyoplankton off Washington, Oregon, and Northern California, August 1980. NMFS Northwest and Alaska Fisheries Center, Seattle, Wash. Proc. Rep. 82-12, 43 p.

43 percent of U.S. exports of edible fishery products ($462 million in 1981). Salmon are anadromous and return to coastal rivers and streams to spawn, but are subject to interceptions by foreign nations during their far-ranging migrations in the ocean.

Recruitment research will focus on chinook, *Oncorhynchus tshawytscha*, and coho, *O. kisutch*, salmon in the Columbia River estuary, in ocean plume and coastal waters off Washington and Oregon, and during their ocean migration off southeastern Alaska. These species and stocks were selected for study because they contain large proportions of tagged fish. A recruitment problem exists in that increased releases of coho salmon from hatcheries since the mid-1970's have accompanied declining returns.

Recruitment studies are aimed at reducing uncertainty in predictions of salmon returns through better understanding of the factors that affect early ocean survival of salmon. This will be acquired experimentally through: 1) Studies on salmon physiology and ecology during the period of transition from fresh to salt water; 2) studies on environmental conditions limiting early ocean survival — particularly food availability and predation; 3) modelling studies to optimize the regimen for release of salmon from hatcheries; and 4) development of predictive models to forecast year-class strength. The environmental factors to be examined include conditions abetting food production, such as upwelling (caused by meteorological events and southward flowing currents) or the formation of temperature fronts (caused by eddy dynamics or current shears).

Ichthyoplankton and Pollution Stress

Under the direction of George Snyder, studies are being conducted at the NWAFC Auke Bay Laboratory on the effects of petrogenic hydrocarbons on the viability of early life stages of coho salmon. Short-term exposures of coho salmon eggs, alevins, and fry to aromatic hydrocarbons common to crude oils demonstrated that sensitivity to the aromatics increased from egg to fry,

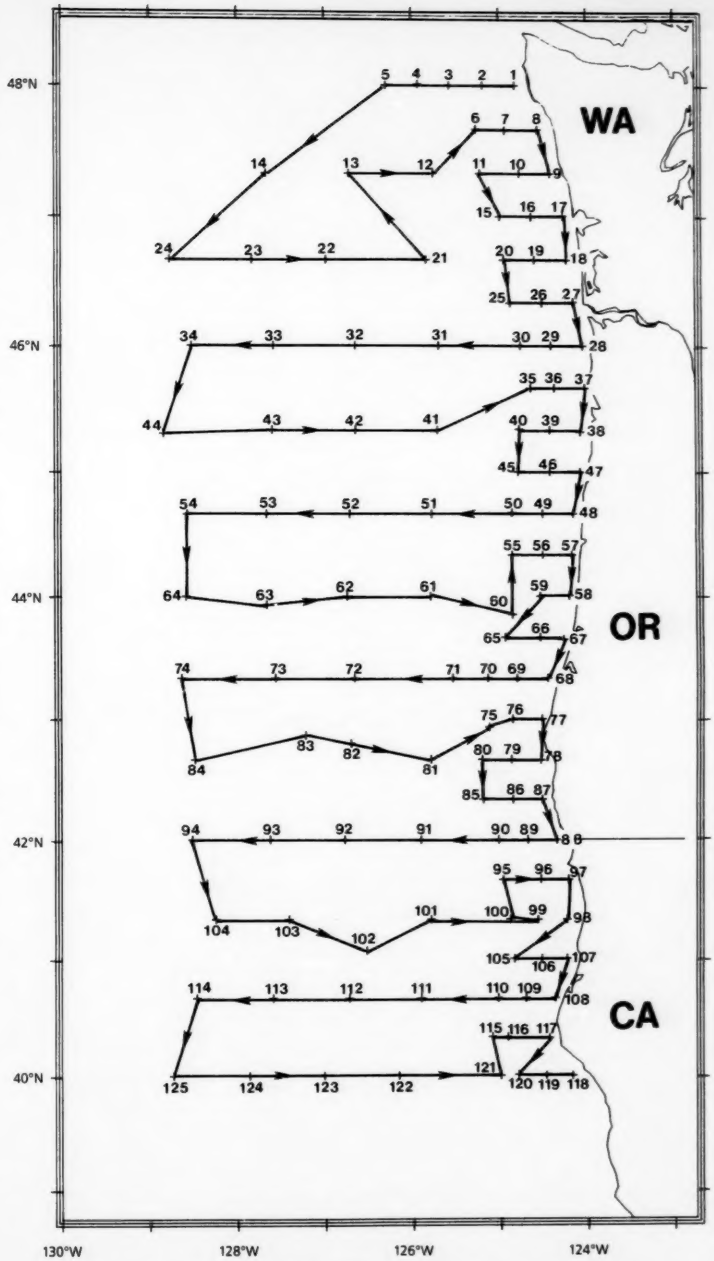
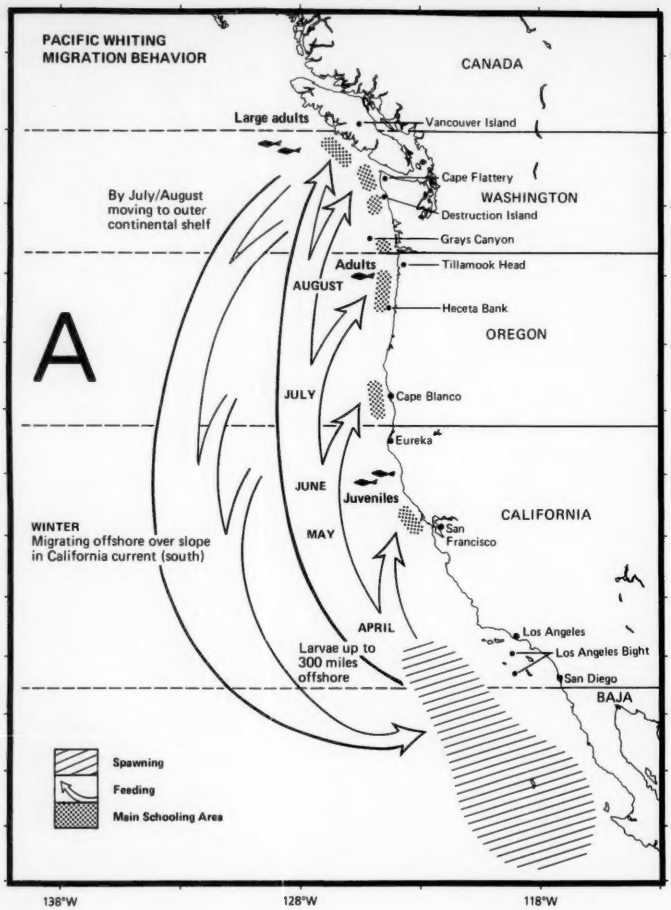


Figure 15. — Station locations and cruise track for the ichthyoplankton surveys within the coastal Washington-Oregon LME — April-May 1980.



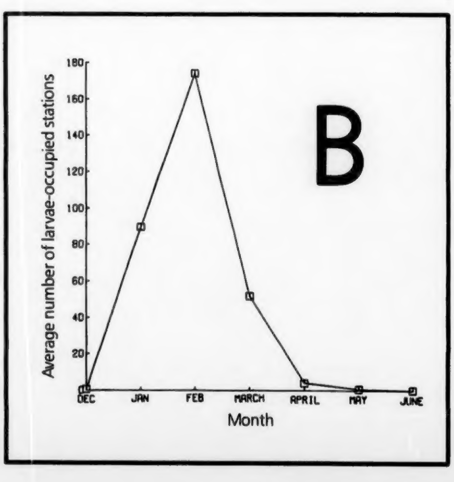


Figure 16. — A = Migratory patterns of Pacific hake. B = seasonal patterns of distribution of larvae, juveniles, and adults of the Pacific hake with relation to spawning, feeding, and schooling areas in the California Current and Washington-Oregon Coast ecosystems. Adapted from Bailey et al. (1982).

with the greatest impact between egg and the early alevin stage (Korn and Rice, 1981).

Northeast Fisheries Center

Stressed Northeast Shelf Ecosystem

The continental shelf ecosystem off the U.S. northeast coast supports a fisheries industry that contributes $1 billion annually to the economies of the coastal states from Maine to North Carolina. However, the fish stocks of the region have been heavily exploited. From 1968 through 1975 the total catchable finfish biomass declined by approximately 50 percent (Fig. 17). This decline was correlated with high fishing mortality (Clark and Brown, 1977). Since 1975, a small recovery trend has been observed among the demersal species (i.e., Atlantic cod, *Gadus morhua*; pollock, *Pollachius virens*; flounders, *Paralichthys* sp., *Hippoglossoides* sp., *Limanda* sp., and *Pseudopleuronectes* sp.). Atlantic herring, *Clupea harengus*; and Atlantic mackerel, *Scomber scombrus*, stocks remain depressed.

The dramatic decline raised several important questions. Would the reduction of predation pressure by the loss of pelagic zooplanktivorous fish result in elevated levels of zooplankton? Would small, fast-growing, opportunistic zooplanktivorous species replace the herring and mackerel populations? Would the depressed stock return to former

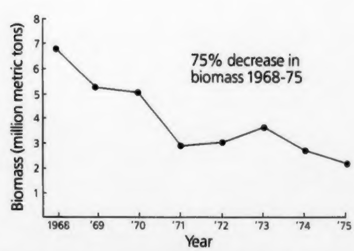


Figure 17. — Decline in the fishable biomass of Georges Bank, Gulf of Maine, and southern New England 1968-75. Adapted from Clark and Brown (1977).

abundance levels with the control of fishing mortality imposed by the establishment of the FMZ and the significant reduction of large-scale factory-trawler operations? In an effort to address these questions, ichthyoplankton sampling was expanded in 1977 to cover the northeast shelf ecosystem and provide fisheries-independent information on the total ichthyoplankton community of the system.

Sampling Strategy

Following the CalCOFI model, a systematic network of sampling for ichthyoplankton was established on a grid network with stations spaced 25-30 km apart over the entire 260,000 km² of the northeast shelf (Fig. 18). At each station, collections were made with paired bongo nets fitted with 0.333 mm and 0.505 mm mesh nets. From two to twelve surveys were made each year from 1974 through 1981. All ichthyoplankton and zooplankton collections were sent to the Polish Sorting Center in Szczecin, Poland, for processing. In addition, from 1977 through 1982, water column sampling was conducted for temperature, salinity, nutrients, oxygen, chlorophyll, and primary production (^{14}C) (Evans and O'Reilly, In press; O'Reilly and Thomas, In press).

Sand Lance Explosion

From our analyses of ichthyoplankton species composition and abundance data, we observed a population explosion of sand lance, *Ammodytes* spp., from 1974 through 1981, coincident with a decline in Atlantic herring and Atlantic mackerel (Fig. 19). A similar coincident shift in abundance occurred in the North Sea where the declining Atlantic herring and Atlantic mackerel stocks appeared to be replaced by increases in the populations of small, fast-growing sprat, *Clupea sprattus*; sand lance, and Norway pout, *Trisopterus esmarkii* (Sherman et al., 1981). NEFC studies under the direction of Wallace Smith and his team at the Sandy Hook Laboratory focus on measuring the impact of the perturbation of sand lance abundance on the production of other fish stocks on the shelf, particularly with respect to any recovery in

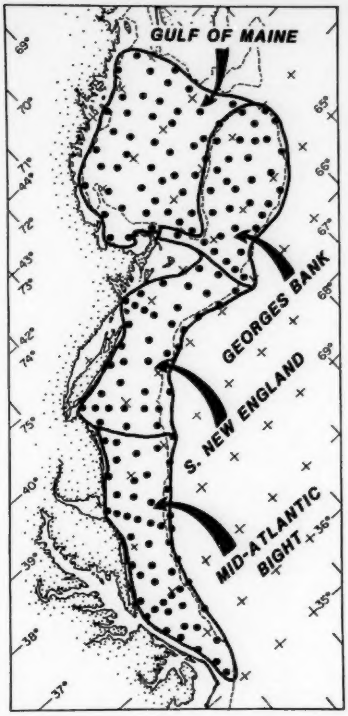


Figure 18. — Station locations for sampling ichthyoplankton on the northeast continental shelf ecosystem.

Atlantic herring and Atlantic mackerel abundance.

Ecosystem Linkages

The 1977-81 MARMAP surveys provided new information on the productivity of the shelf ecosystem. With the exception of the shelf-slope front, the shelf ecosystem is highly productive. Mean annual values of carbon production ranged from 260 g C/m² in the mid-shelf off Cape Hatteras to 450 g C/m² on Georges Bank (O'Reilly and Busch, In press) (Fig. 20). The shelf ecosystem was divided into subareas based on areal differences in bathymetry, hydrography, circulation, and population structure. Recurrent annual cycles of zooplankton abundance were observed from 1977 through 1981 in each of four

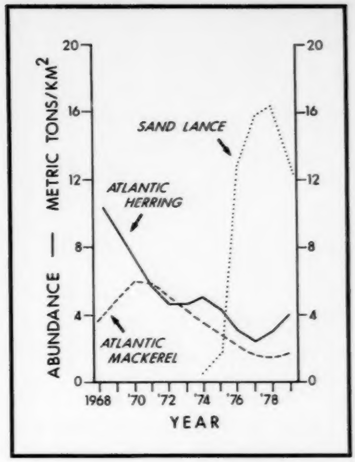


Figure 19. — Decline of Atlantic herring and mackerel and apparent replacement by the small, fast-growing sand lance in the northeast continental shelf ecosystem.

subareas — Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic Bight (Sherman et al., In press).

Wallace Smith and his team at the Sandy Hook Laboratory have observed distribution patterns of larvae that are related to circulation, bathymetry, and plankton production. The "Shelf Gyre" species include redfish, *Sebastes* sp., in the Gulf of Maine, and Atlantic cod and haddock on Georges Bank. Further south the "Shelf Plain" species include bluefish, *Pomatomus saltatrix*, in the Mid-Atlantic Bight and Southern New England, and searobin, *Prionotus* spp., in the same regions. "Shelf Estuarine" species include the northern anchovy, Engraulidae; and croaker, *Micropogonias undulatus*, in the Mid-Atlantic Bight area. Two "Shelf Migrants" were identified: 1) The Atlantic mackerel migrates from the Mid-Atlantic Bight northward in spring in synchrony with the northern spring increase in zooplankton, and 2) the Atlantic menhaden, *Brevoortia tyrannus*, an autumn spawner, was observed to migrate southward from Southern New England

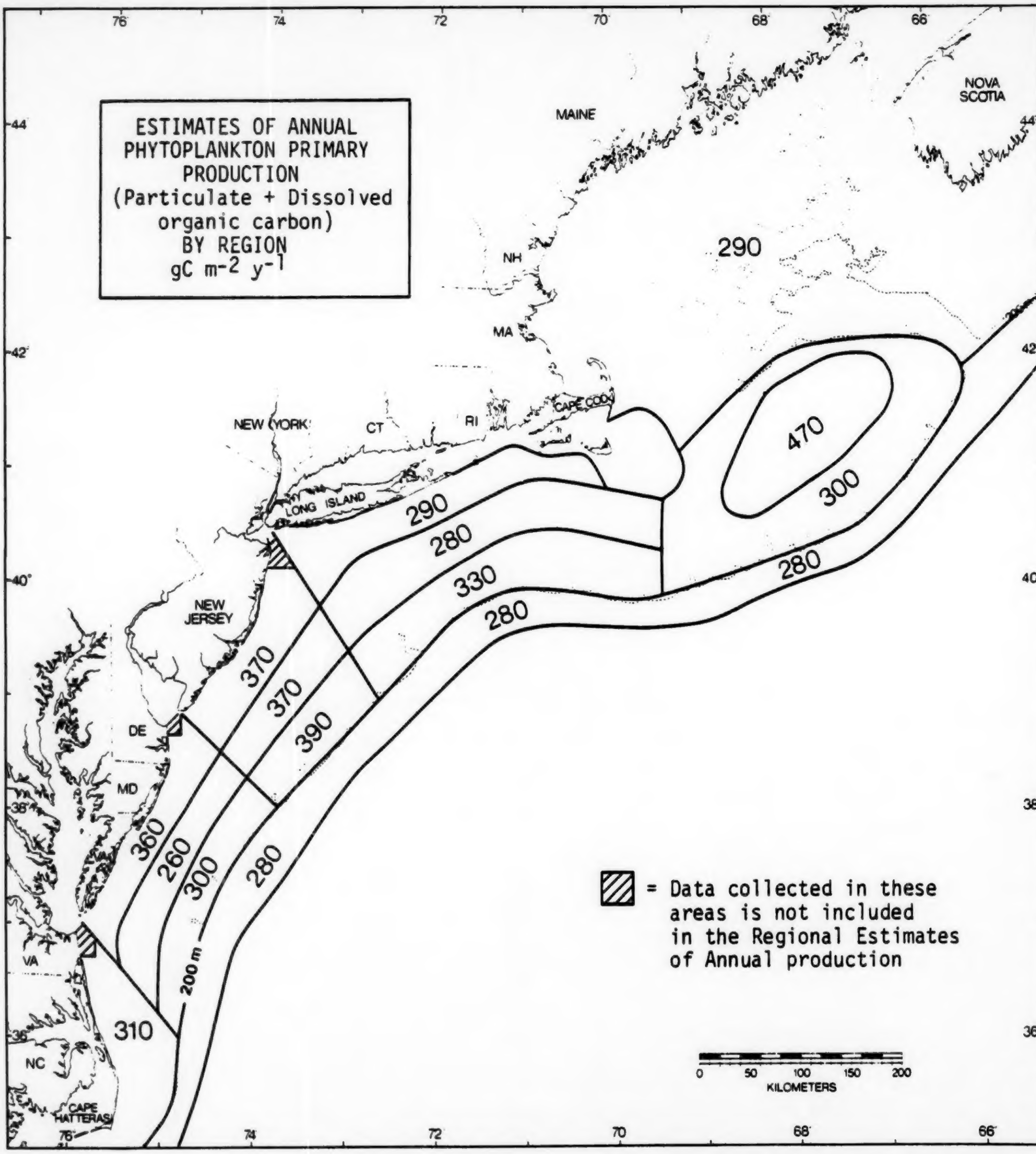


Figure 20. — Average annual primary production (g C/m²) per year based on the MARMAP ^{14}C method (O'Reilly and Busch, In press).

to the Mid-Atlantic Bight in autumn from an area of moderate zooplankton abundance to the highest concentrations of zooplankton on the shelf in this season off Delaware and Chesapeake Bays. Silver hake, *Merluccius bilinearis*; other hakes, *Urophycis* spp. (predominantly red hake, *Urophycis chuss*); and sand lance, *Ammodytes* sp., are found in each of the four subareas and are classified as "Ubiquitous Shelf" species.

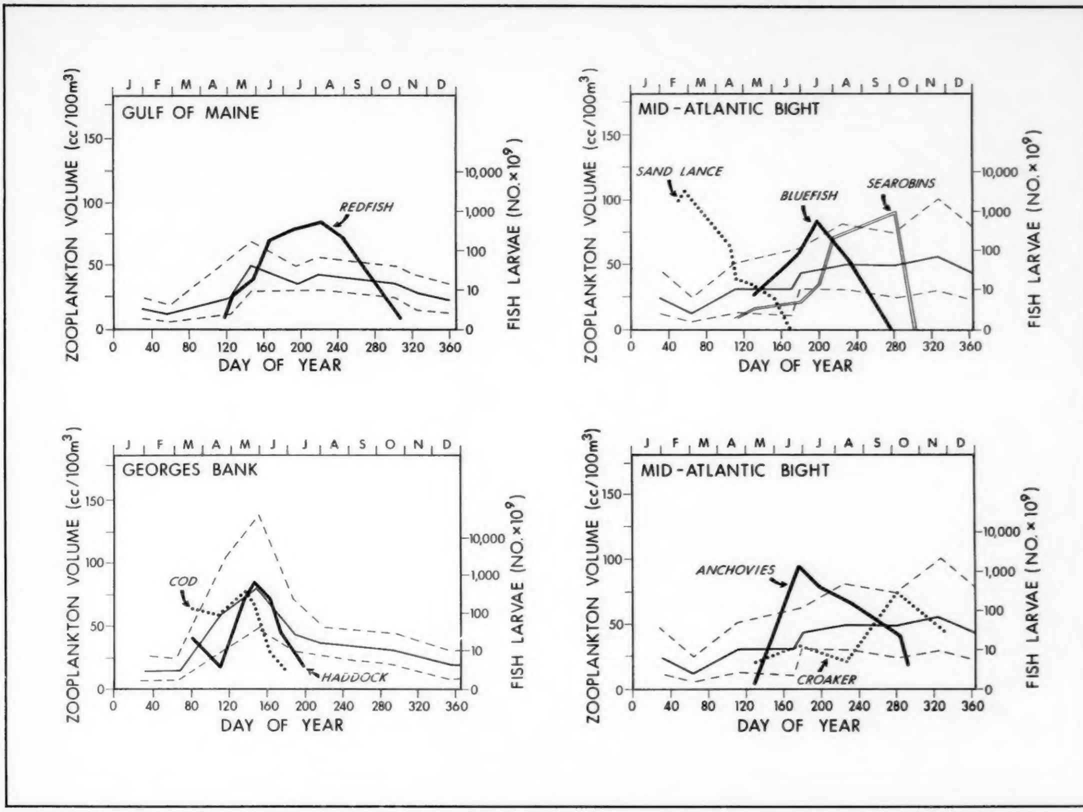


Figure 21. — Synchrony of peak larval production plotted with median zooplankton abundance in four subareas of the northeast shelf ecosystem — Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic Bight. The single light line represents the 5-year (1977-81) mean values of zooplankton volumes (cc/100 m^3) bounded by two standard errors (dashed lines). Mean ichthyoplankton species abundance (1977-80) (N $\times$ 10^9) is shown for: Gulf of Maine redfish (bold line); Georges Bank cod (dotted line), haddock (bold line); Mid-Atlantic Bight sand lance (dotted line, upper right), bluefish (bold line), and searobins (double line); anchovies (bold line, lower right), and croaker (dotted line, lower right).

Spawning strategies are adaptations of the spawning biomass to topographic and circulation features of the northeast shelf and the annual plankton production cycle in each of the four subareas — Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic Bight. Under average conditions, the gyre, shelf-plain, and shelf-migratory spawners reach peak abundance in synchrony with the seasonal pulses in their zooplankton prey (Fig. 21). The ubiquitous spawners appear to maintain relatively high densities of eggs over a wide temporal and spatial range within the shelf ecosystem, thereby enabling them to respond rapidly to favorable environmental conditions (Sherman et al.[12]). Studies off the northeast coast have demonstrated that sand lance is an opportunistic species that can be considered a temporary replacement for the overfished mackerel and herring populations (Sherman et al., 1981).

[12]Sherman, K., W. Smith, W. Morse, M. Berman, J. Green, and L. Ejsymont. 1983. Spawning strategies of fishes in relation to circulation patterns, phytoplankton production, and pulses in zooplankton abundance off the northeastern United States. ICES C.M.1983/L:28.

Spawning Stock Estimates

Among the species for which spawning biomass estimates were made from the MARMAP ichthyoplankton collections are silver hake, mackerel, sand lance, bluefish, and yellowtail flounder, *Limanda ferruginea*. Other species targeted for biomass estimates are haddock, Atlantic cod, redfish, and searobin.

Density-Dependent Recruitment Studies

To improve forecasts of abundance it is necessary to obtain a better understanding of the relationship between the abundance of early developmental stages and new recruits to the fisheries. Within the sampling network of the MARMAP multispecies ichthyoplankton surveys, studies are conducted of the factors controlling growth and survival of the target species Atlantic cod and haddock. Age and growth and predator-prey studies of larvae are directed by Gregory Lough and his team at the NEFC Woods Hole Laboratory. Under the direction of Geoffrey Laurence of the NEFC Narragansett Laboratory, studies are now underway to confirm laboratory determinations of optimal prey densities with at-sea experiments on Georges Bank on the availability and abundance of suitable densities of zooplankton prey of cod and haddock (Fig. 22). Plans are also being prepared to conduct predation experiments on eggs and larvae in large enclosures. Preliminary observations made by Geoffrey Laurence and his team indicate that larval growth and survival are very high in large, predator-free, flow-through net mesh enclosures placed in a highly productive estuarine environment (Laurence et al., 1979).

Density-Independent Recruitment Studies

Warm-core rings have been observed entraining large volumes of shelf water across the shelf slope front into a nutrient-poor environment. It has been hypothesized that eggs and larvae of shelf species advected off the highly productive shelf in an entrainment feature would not survive in the prey-poor environment. Collections made in an entrainment experiment conducted by Geoffrey Laurence and his team on the survival of ichthyoplankton in an entrainment feature revealed that no shelf species were in the entrainment. The only ichthyoplankton observed in the collections were larvae of bathypelagic shelf-slope species, suggesting that warm-core rings are not responsible for advective mortality of shelf larvae.

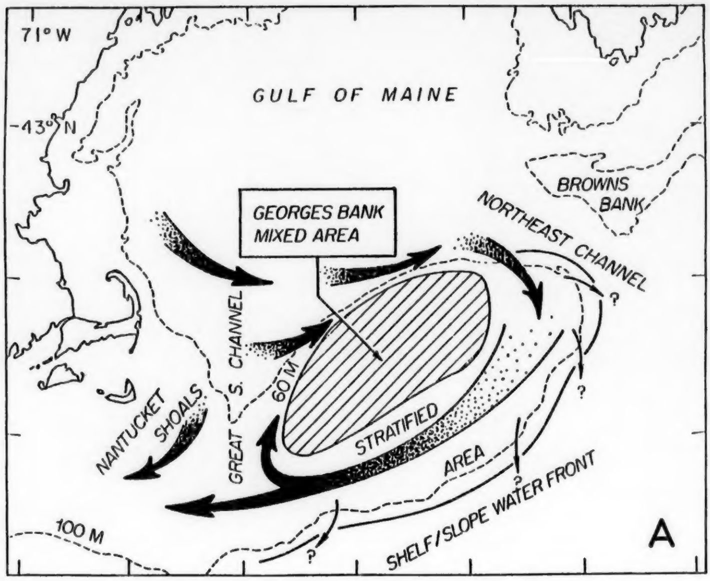
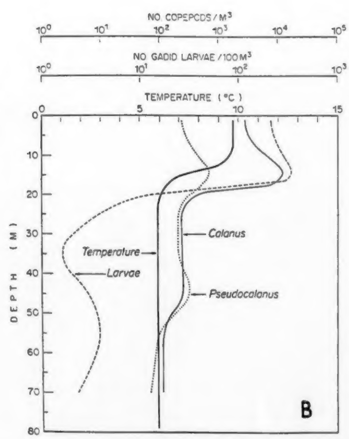


Figure 22. — A = Schematic representation of the well-mixed and stratified waters on Georges Bank and mean circulation flow (arrows) during spring and summer. B = Vertical distribution of gadid (haddock and cod) larvae and dominant copepods (*Calanus finmarchicus*, *Pseudocalanus* sp.) in relation to thermocline on the southeast part of Georges Bank before storm. (MOCNESS-1 m, 0.333-mm mesh, 21 May 1981, 2303-2358 D.S.T., 40°55′N, 67°16′W. Bottom depth: 78-80 m.) Note different log-scales used for copepods and gadid larvae.



Replicate experiments are planned to confirm these preliminary results (Laurence and Burns, 1982).

Pollution Studies

In cooperation with the U.S. Fish and Wildlife Service, studies were made under the direction of Lawrence Buckley (Narragansett Laboratory) of the viability of striped bass larvae from parent stock exposed to heavy metals and other toxins. Initial results indicate significant impact of the exposure to larvae hatched from the Hudson River parent stock.

Other Narragansett Laboratory pollution-related studies underway in cooperation with the Environmental Protection Agency are focused on the impacts of exposures of larvae to urban

sludge compounds identical to those now being disposed of on the continental shelf by the State of New York. One of the encouraging advances by Lawrence Buckley and his group is the application of an RNA/DNA analysis for determining the growth potential of larvae collected routinely during the MARMAP surveys. High ratios indicate a "healthy" physiological condition for the larvae, whereas low values indicate that the growth potential of the larvae is impaired (Buckley, 1980, 1982). The RNA/DNA analysis will be conducted on batch samples of larvae collected on MARMAP surveys in an effort to classify, temporally and spatially, larvae in "poor condition."

Management of Large Marine Ecosystems

A growing awareness by marine resource managers of the interrelationships among species and their environments has led to legislated mandates for the conservation and management of total ecosystems. This concern is expressed in the language used in the Magnuson Fishery Conservation and Management Act of 1976 which requires that:

"...Conservation and management measures shall be based on the best scientific advice available.... To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination."[13]

A good deal of the precedent can be attributed to the two-tiered management practice enacted by the International Commission for North Atlantic Fisheries (ICNAF). In 1972 ICNAF established total biomass quotas of finfish for the northwest Atlantic and assigned total allowable catch levels to all target species of the fisheries to be followed on an annual basis (ICNAF, 1973; Grosslein et al., 1979).

The most recent example of the movement toward total ecosystem management is found in the language of the Commission for the Conservation of Antarctic Marine Living Resources. Article II of the Convention calls for holistic management wherein: "...The regime should provide for the effective conservation of the living marine resources of the Antarctic ecosystem as a whole...." Considerable progress has been made by the international scientific community in the coordination and integration of studies in the Antarctic leading to population assessments of the principal ecosystem populations, including krill, *Euphausia* spp., and its predators and prey under the aegis of the Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS) program (Beddington and May, 1982). The approach in dealing with the world's largest marine ecosystem has been a combination of international krill biomass assessment surveys, an analysis of catch data, and surveys of marine birds, mammals, and fish (Laws, 1980; Everson, 1981; Pommeranz et al., 1981; Hureau, 1982; BIOMASS Working Party on Fish Biology, 1982; BIOMASS Working Party on Bird Ecology, 1982a,b,c). Initial results of this effort have been most effective in refining estimates of krill biomass in the region (BIOMASS Report Series, 1980, 1982).

For effective management of any LME, it is necessary to survey the populations and their environments. Unfortunately, surveys can become dull, routine affairs, but they are critical components of a total ecosystem resources assessment program. Technical advances in hydroacoustics, satellite remote sensing of ocean features (Lasker et al., 1981; Peláez and Guan, 1982), and electronic particle sampling and data processing at sea (Lough and Potter, In press) and in the laboratory (Jeffries et al., 1980), when applied to the MARMAP type multispecies ichthyoplankton time-series surveys and target-species recruitment studies, will contribute to increased sampling efficiencies and reduced costs of the assessment surveys of large marine ecosystems.

[13]Fishery Conservation and Management Act of 1976, USA (FCMA). Public Law 94-265, 94th Congress, H.R. 200, 13 April 1976.

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Shaping and Assembling Webbing

CONRAD W. RECKSIEK

Introduction

In this paper I present a simple method for reckoning a taper in webbing. I also present methods for cutting out and assembling trawlnet sections. Using techniques of whole number arithmetic, and by considering various "whole number properties" of webbing (or similar grid, e.g., a checkerboard), the novice should be able to cut out and assemble trawlnet sections from a traditional net plan. The methodology presented here should be applicable to most operations involving tapering of nets.

I wrote this paper to describe the web shaping process in completely numerical terms so the various associated calculations could be made with a computer. By using the principles described here, the net designer and builder can create their own algorithms and program the various personal or business microcomputers available today to perform calculations to suit their own specialized requirements.

A companion article entitled "A microcomputer program for the calculation of a trawlnet section taper" (Martin and Recksiek, 1983) illustrates such a program. Most such programs would input dimensions or tapers and output an unknown dimension or taper. For instance, a routine to calculate trawlnet belly section tapers would take the number of meshes on the "wide end," the number of meshes on the "narrow end," and the number of meshes in depth as input, and present, as output, the taper characteristics in a standard numerical shorthand.

Other potential applications of automating the calculations include development of computerized graphics routines which display web sections. An immediate and straightforward application of such graphics routines is to quickly and easily draw net plans which show every mesh. Being able to make similar displays in three dimensions is an initial step in visually portraying the response of a net section in numerically modeled flows. One can also envision an application where a computer would control a net making machine. This would permit a manufacturer to supply orders for "pre-shaped" sections.

There is a body of literature on the tapering of webbing. Exemplary works are by Garner (1981, 1973), Libert and Maucorps (1978), Nédélec (1975), and Hillier (1981). The first three use a system based on "meshes lost or gained" in which a table of cutting rates is presented. Each tabular element can be associated with certain gains or losses of meshes and the correct taper reckoned accordingly. Hillier (1981) presented a special series of tapering formulae which can be applied to most tapering problems. Hillier's method is well known and applied in the United States.

A traditional terminology exists to describe the tapering of webbing. In this paper I will use that of Hillier (1981). Figure 1 illustrates a rectangular section of webbing in which tapered cuts have been made. The terminology distinguishes between cuts according to which side of the "diagonal" they are on. Cuts above the diagonal are termed body cuts. These are said to be formed of bars (single cut strands) and points (two cut strands). Similarly, the taper below the diagonal, a jib cut, is said to be formed of bars and meshes.

Exemplary tapers are depicted in Figure 1. Body cut A to B consists of four sets of 2 bars 1 point; jib cut E to F

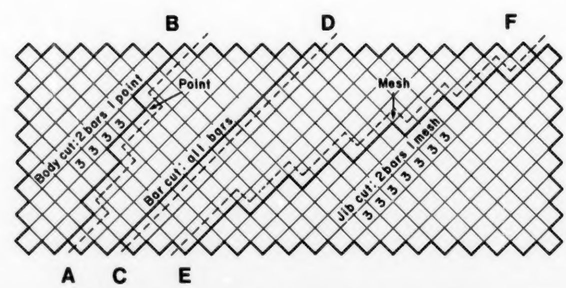

Figure 1.—Representative diagonal cuts, or tapers, in webbing. The tapered edges are drawn as heavy solid lines, with knife paths across the cut strands drawn as dashed lines. Body cut A to B forms bars and points; jib cut E to F forms bars and meshes. Note how tapers are described in traditional terms (2 bars 1 point) and as an integer sequence (3, 3, 3, 3).

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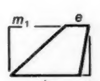
Table 1.— Summary of notation and equations used in the determination of body-cut net tapers. For explanation see text.

Text equation numbers	Equation		Explanation
(1.2), (6.6)	$T = U(S-1)+R(S)$		General tapering formula: U and R, points; S, steps/point; T, total steps.
(1.3)	Steps $= n+m-1$		Total steps across a net: n, mesh distance vertically; m, mesh distance horizontally.
(2.1)	Points $= n-m+1$		Number of points in a net taper: n, mesh distance vertically; m, mesh distance horizontally.
(6.1)	$T = P(S-1)+R$		Alternative form of the general tapering formula: P, points; S, steps/point; R, steps remainder (this expression is equivalent to $T = U(S-1)+R(S)$ by letting $P = (U+R)$.
(10.1)	$T = F\left[U'(S-1)+R'(S)\right]$		General case of $T = U(S-1)+R(S)$ where F is a common factor of U and R, and U' and R' have no common factors.
(11.1)	$t = (2m-2)+k$		Belly top formula used to determine m: t, meshes across top, or wide end; k, meshes across bottom, or narrow end; m, horizontal mesh distance of taper.
(13.1)	$e = (k-n)+m$		Wing formula used to determine m: e, meshes across narrow end; k, meshes across wide end; n, depth or vertical distance; m, horizontal mesh distance.
(15.1)	$e = (k-m_1)+m_2$ $m_1 > m_2$		Double-taper wing formula used to determine either m_1 or m_2: e, meshes across narrow end; k, meshes across wide end; m_1 and m_2, horizontal distances for each taper.

consists of seven sets of 2 bars 1 mesh; bar cut C to D consists of all bars.

The distinction between body cuts and jib cuts is important. The points of the body cut form sider knots, while meshes of the jib cuts form pickups. Thus the orientation of the webbing, or "run of the twine," must be considered. In this paper, the run of the twine will be assumed to be from top to bottom. (According to Libert and Maucorps (1978), page 5, the "run of the twine" is side to side. The reader should use caution in comparing references.)

I present here a method of reckoning tapers based upon arithmetic and simple algebra. This development does not exactly match the traditional twine terminology, so I will introduce a few new terms. I will, however, describe operations in traditional terms for purposes of comparison.

In the next section of this paper, Reckoning the Taper, I present new terminology and the tapering principles. Essentially, I describe the rationale behind various tapering formulae. The reader should consult Table 1 where the important equations and notations are summarized. In the next section I develop Table 1 equations (1.2) through (10.1). Table 1 equations (11.1) through (15.1) are used to calculate tapers and dimensions of webbing pieces used in building trawlnets. These are explained in subsequent sections of this article.

At this point, after reviewing Table 1, I encourage the reader to skim the Figures, particularly Figures 8-15 on pages 33-40. They should convey an impression of what the fundamental principles in the next section are leading toward and clarify the uses of some of the notations summarized in Table 1.

Reckoning the Taper

Tapering a piece of netting is analogous to stepping across a grid or checkerboard. A taper can be considered to be a pathway (really made of knife cuts) across the grid formed by the knots and strands of webbing. In Figure 2, two separate pathways from A to exemplary end meshes B and D are illustrated. To reach point B, one "steps" either "upward" or along the diagonal. To reach D, one "steps" either "sideways" or along

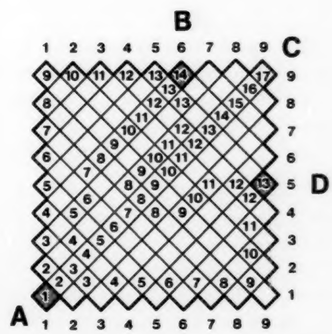


Figure 2.— Steps required to achieve tapers. Tapering webbing is analogous to stepping across a grid or checkerboard. To reach meshes B and D from starting mesh A, exactly 14 and 13 steps, respectively, are required regardless of the path. Various paths are illustrated here by numbering steps.

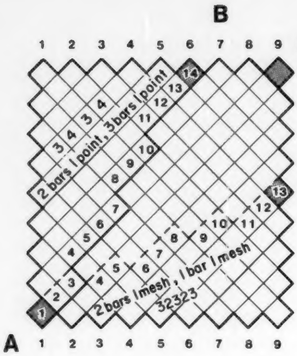


Figure 3.— Steps across webbing with tapers indicated: Body cut A to B, solid line; jib cut A to D, dashed line.

the diagonal. Note that exactly the same number of steps (14) are taken to reach point B from A. No matter how one proceeds across the grid in the direction of B (up and diagonally), 14 steps are required. Likewise, to reach D, 13 steps are required (sideways and diagonally). And, to reach C, exactly 17 steps along the diagonal are required.

Many pathways (cuts) across the grid (web) are possible. Our task is to present rules to traverse the web in as straight a path as possible. In Figure 2, the path from A to C will be perfectly straight, whereas other paths, say from A to B, will involve moving along the diagonal and moving upward.

In Figure 3, an exemplary grid is presented where steps across are subtended by darkened lines which represent finished edges of a taper. Here, the tapers lack the uniformity of those in Figure 1. For example, the taper A to B mixes cuts of 4 steps per point with cuts of 3 steps per point in a sequence 3, 4, 3, 4. This would be a body cut of 2 bars 1 point and 3 bars 1 point. Expressing the taper as a whole-number sequence, and not as a traditional mix of bars and points, is the heart of the tapering principle being presented here. Expressing the tapers as a sequence of numbers turns out to have the advantage of expressing both simple and complex tapers in an easy and straightforward manner.

Alternative tapering paths across the webbing may exist (i.e., there may be an element of choice in selecting which strands to cut to form the taper). In Figure 4, alternative paths are diagrammed. In this particular case, one could have structured the taper as 3, 4, 3, 4 or 4, 3, 4, 3. In fact, the sequences 4, 4, 3, 3 or 3, 3, 4, 4 could also have been used, but then the taper would lack "symmetry."

Referring to Figure 4, we could express the body cut A to B, 3, 4, 3, 4 as follows:

$$14\text{ steps} = \begin{bmatrix}2\\ \text{points}\end{bmatrix}\begin{bmatrix}3\\ \text{steps}\\ \text{per}\\ \text{point}\end{bmatrix} + \begin{bmatrix}2\\ \text{points}\end{bmatrix}\begin{bmatrix}4\\ \text{steps}\\ \text{per}\\ \text{point}\end{bmatrix}. \qquad (1.1)$$

That is, the sum of the integers in the sequence 3, 4, 3, 4 is equal to the total number of required steps across the web.

Equation (1.1) is an example of the fundamental tapering algorithm or rule being presented in this paper. This whole-number expression simply writes the total number of steps across the grid in the form:

$$T = U\,(S-1) + R(S) \qquad (1.2)$$

where

$$\begin{aligned} T &= \text{total steps,}\\ U \text{ and } R &= \text{points, and}\\ S &= \text{steps/point.}\end{aligned}$$

Once the taper is expressed in this form, an integer sequence which specifies the cut follows immediately. This sequence has the following general form: $(S-1)_1$, $(S-1)_2$, $(S-1)_3$, ... $(S-1)_U$, S_1, S_2, S_3, ...S_R.

Although equation (1.2) is not "very compatible" with traditional twine terminology, it should be noted that $S-1$ and S are the number of strands cut in the diagonal direction below each point (for body cuts). For example, for the body cut A to B in Figure 3, note that $S = 4$ and that $S-1 = 3$. To make the taper, one would cut 3 strands along the diagonal, cut the upper right strand to form the point, cut 4 more strands along the diagonal, cut the upper right strand to make the second point, etc.

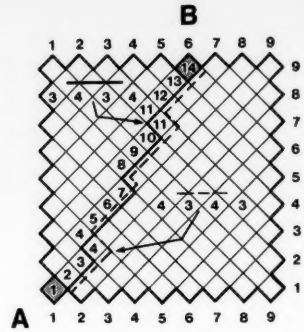


Figure 4.— Alternative tapers for the body cut A to B: 3, 4, 3, 4, solid line; 4, 3, 4, 3, dashed line. A total of 14 steps are taken regardless of which pathway or taper is used.

The total number of steps across the web to form the taper must first be known to reckon the taper. Finding the total number of steps is the first stage in what ultimately will result in the final sequence of integers given by equation (1.2). The total number of steps is a simple sum of meshes "up" and diagonally for a body cut ("sideways" and diagonally for a jib cut).

Specifically, for a body cut where points and bars are formed, in finding total steps, one needs to know a vertical distance (expressed as grid steps), n, and a horizontal distance, m, from the starting mesh (or square). The distances n and m are represented in Figure 5. Note, when examining this figure, that two situations are possible: 1) When n and m are both whole numbers, as in 5(a) and 2) when m and n are both whole numbers plus one-half, as in 5(b). Note that in the latter case a three legger must occur somewhere in the tapered piece. This characteristic is important and will be discussed in detail later.

In any event, for a body cut, total steps are given by:

$$\text{Steps} = n+m-1. \qquad (1.3)$$

This equation holds for jib cuts except that the roles of m and n are reversed, i.e., m refers to the vertical distance, n to the horizontal (see Figure 5, jib cuts A to D).

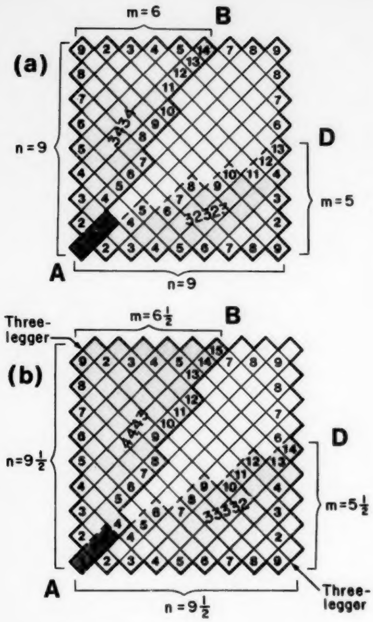


Figure 5.—(a) Illustration of mesh distances n and m. For a taper involving points, A to B, n is the vertical distance, whereas for a taper involving meshes, A to D, n is the horizontal distance. (b) Illustration of the terminal mesh (B and D) being a fractional distance in meshes from the column n (for points) or row n (for meshes). Note three-leggers in the finished pieces. Note that (a) is analogous to stepping from a black to a black square, A to B and A to D, on a checkerboard, while case (b) is analogous to stepping from a black square to a red one, A to B and A to D.

Having determined the total number of steps as a sum of mesh distances (equation (1.3)), one next determines the number of points (or meshes) which will be formed in the taper. For body cuts, this is given by the equation:

$$\text{Points} = n-m+1, \tag{2.1}$$

and, as with equation (1.3), the roles of n and m are reversed for jib cuts. To illustrate total number of steps together with the number of points (or meshes), consider Figure 5(a). For the body cut A to B:

$$n+m-1 = 9+6-1 = 14 \text{ steps} \tag{2.2}$$

and

$$n-m+1 = 9-6+1 = 4 \text{ points.} \tag{2.3}$$

Observe that points occur at steps 3, 7, 10 and 14.

For the jib cut A to D:

$$n+m-1 = 9+5-1 = 13 \text{ steps} \tag{2.4}$$

and

$$n-m+1 = 9-5+1 = 5 \text{ meshes.} \tag{2.5}$$

Meshes occur at steps 3, 5, 8, 10 and 13.

Now consider Figure 5(b). Here, tapers A to B and A to D end at half-mesh distances. For the body cut A to B:

$$n+m-1 = 9\tfrac{1}{2}+6\tfrac{1}{2}-1 = 15 \text{ steps} \tag{2.6}$$

and

$$n-m+1 = 9\tfrac{1}{2}-6\tfrac{1}{2}+1 = 4 \text{ points.} \tag{2.7}$$

For the jib cut A to D:

$$n+m-1 = 9\tfrac{1}{2}+5\tfrac{1}{2}-1 = 14 \text{ steps} \tag{2.8}$$

and

$$n-m+1 = 9\tfrac{1}{2}-5\tfrac{1}{2}+1 = 5 \text{ meshes.} \tag{2.9}$$

Therefore, the equation

$$\frac{n+m-1}{n-m+1} = \frac{\text{steps}}{\text{points (or meshes)}} \tag{3.1}$$

is sufficient to numerically describe tapers.

Once steps and points (assuming a body cut) are determined, one can express the taper through some simple arithmetic in the form

$$\text{total steps} = [\text{points}]\left[\frac{\text{steps}}{\text{point}}\right] + [\text{steps remainder}]. \tag{3.2}$$

For example, in Figure 5(a), in the body cut A to B we have

$$\frac{n+m-1}{n-m+1} = \frac{14 \text{ steps}}{4 \text{ points}}. \tag{3.3}$$

With 4 as a divisor of 14, the largest whole number quotient is 3 where $3\times 4 = 12$. With 2 steps remainder, one can write:

$$14 \text{ steps} = [4 \text{ points}]\left[\frac{3 \text{ steps}}{\text{per point}}\right] + [2 \text{ steps remainder}]. \tag{3.4}$$

Note that the taper, so far, consists of 4 sets of 3 steps/point with 2 steps left over. Numerical manipulation is now necessary to remove the remainder and express the taper in the form of equation (1.2). If one were to "modify" equation (3.4) so that the 2-step remainder were "absorbed" into the expression, a taper would be described. This process involves expressing the factor $n-m+1$ (4 in this example) as a sum of two numbers, one of which is the remainder. This is illustrated as follows:

$$14 \text{ steps} = \begin{bmatrix} 4 \\ \text{points} \end{bmatrix}\begin{bmatrix} 3 \\ \text{steps} \\ \text{per} \\ \text{point} \end{bmatrix} + \begin{bmatrix} 2 \\ \text{steps} \end{bmatrix} \tag{3.5}$$

(fundamental expression)

$$= \left(\begin{bmatrix} 2 \\ \text{points} \end{bmatrix} + \begin{bmatrix} 2 \\ \text{points} \end{bmatrix}\right)\begin{bmatrix} 3 \\ \text{steps} \\ \text{per} \\ \text{point} \end{bmatrix} + \begin{bmatrix} 2 \\ \text{steps} \end{bmatrix} \tag{3.6}$$

(modify first term)

$$= \left[\begin{bmatrix} 2 \\ \text{points} \end{bmatrix}\begin{bmatrix} 3 \\ \text{steps} \\ \text{per} \\ \text{point} \end{bmatrix} + \begin{bmatrix} 2 \\ \text{points} \end{bmatrix}\begin{bmatrix} 3 \\ \text{steps} \\ \text{per} \\ \text{point} \end{bmatrix}\right] + \begin{bmatrix} 2 \\ \text{steps} \end{bmatrix} \tag{3.7}$$

(separate terms)

$$= \left[\begin{bmatrix} 2 \\ \text{points} \end{bmatrix} \begin{bmatrix} 3 \\ \text{steps} \\ \text{per} \\ \text{point} \end{bmatrix} \right] + \left[\begin{bmatrix} 2 \\ \text{points} \end{bmatrix} \begin{bmatrix} 3 \\ \text{steps} \\ \text{per} \\ \text{point} \end{bmatrix} \right] + \begin{bmatrix} 2 \\ \text{points} \end{bmatrix} \begin{bmatrix} 1 \\ \text{step} \\ \text{per} \\ \text{point} \end{bmatrix} \qquad (3.8)$$

(Recombine terms and rewrite the remainder in the unit "points×steps/point").

Note that the last two terms share a common factor, 2 points. These therefore can be combined to write the equation in final form:

$$14 \text{ steps} = \left[\begin{bmatrix} 2 \\ \text{points} \end{bmatrix} \begin{bmatrix} 3 \\ \text{steps} \\ \text{per} \\ \text{point} \end{bmatrix} \right] + \left[\begin{bmatrix} 2 \\ \text{points} \end{bmatrix} \begin{bmatrix} 3 \\ \text{steps} \\ \text{per} \\ \text{point} \end{bmatrix} \right] + \begin{bmatrix} 1 \\ \text{step} \\ \text{per} \\ \text{point} \end{bmatrix} \qquad (3.9)$$

$$= \begin{bmatrix} 2 \\ \text{points} \end{bmatrix} \begin{bmatrix} 3 \\ \text{steps} \\ \text{per} \\ \text{point} \end{bmatrix} + \begin{bmatrix} 2 \\ \text{points} \end{bmatrix} \begin{bmatrix} 4 \\ \text{steps} \\ \text{per} \\ \text{point} \end{bmatrix}. \qquad (3.10)$$

This is in the form of equation (1.2). A taper sequence of 3, 3, 4, 4 is now indicated. For symmetry, one would cut the taper at 3, 4, 3, 4 or 4, 3, 4, 3. Incidentally, an algorithm for explicitly specifying the sequence will be presented later. Anyway, equation (3.10) indicates a taper of the pattern 2 bars 1 point, 3 bars 1 point repeated twice.

To illustrate reckoning a jib cut, consider A to D in Figure 5(a):

$$\frac{n+m-1}{n-m+1} = \frac{9+5-1}{9-5+1} = \frac{13 \text{ steps}}{5 \text{ meshes}} \qquad (4.0)$$

or, in the form of equation (3.2),

$$13 \text{ steps} = \begin{bmatrix} 5 \\ \text{meshes} \end{bmatrix} \begin{bmatrix} 2 \\ \text{steps} \\ \text{per} \\ \text{mesh} \end{bmatrix} + \begin{bmatrix} 3 \\ \text{steps} \end{bmatrix}. \qquad (4.1)$$

Leaving out the units for brevity, the process is as follows:

$$13 = (5)(2)+3 \qquad (4.2)$$
(fundamental equation)

$$= (2+3)(2)+3 \qquad (4.3)$$
(modify first term)

$$= (2)(2)+(3)(2) +3 \qquad (4.4)$$
(write separate terms)

$$= (2)(2) + (3)(2)+(3)(1) \qquad (4.5)$$
(recombine terms)

$$= (2)(2)+(3)(3) \qquad (4.6)$$
(combine last terms to complete arithmetic).

This expression now indicates a sequence of 3, 2, 3, 2, 3 (as in Figure 5(a), A to D).

For Figure 5(b) and for the body cut A to B we have

$$\frac{n+m-1}{n-m+1} = \frac{9\tfrac{1}{2}+6\tfrac{1}{2}-1}{9\tfrac{1}{2}-6\tfrac{1}{2}+1} = \frac{15}{4} \qquad (5.0)$$

and

$$15 = (4)(3)+3 \qquad (5.1)$$
(fundamental equation)

$$= (1+3)(3)+3 \qquad (5.2)$$
(modify first term)

$$= (1)(3)+(3)(3) +3 \qquad (5.3)$$
(write separate terms)

$$= (1)(3)+(3)(3)+(3)(1) \qquad (5.4)$$
(recombine terms)

$$= (1)(3)+(3)(4) \qquad (5.5)$$
(complete manipulation).

This indicates a body cut of 4, 4, 4, 3 or 3, 4, 4, 4. Note again that a three-legger has been drawn in the upper left corner of the tapered piece. Note the three-legger in the jib cut piece also.

In a sense, tapering an exact mesh distance as in Figure 5(a) is akin to moving from a black square to a black square on a checkerboard. When tapering to a mesh which is a half-mesh distance away, as in Figure 5(b), one has a situation similar to moving from a black square to a red square.

The process just described can be generalized. Equations (6.1) through (6.6) show the general processes illustrated in equations (3.3) through (3.10), (4.0) through (4.6), and (5.0) through (5.5). We begin by writing total steps as:

$$T=P(S-1)+R, \qquad (6.1)$$

where T = total steps,
P = points,
$S-1$ = steps/points, and
R = steps remainder.

If one rewrites equation (6.1) as

$$T = (P-R+R)(S-1)+R, \qquad (6.2)$$

and letting $U = P-R$ and

$$T = (U+R)(S-1)+R, \qquad (6.3)$$

then

$$T = U(S-1)+R(S-1)+R \qquad (6.4)$$

$$= U(S-1)+R(S)-R(1)+R \qquad (6.5)$$

$$= U(S-1)+R(S) \qquad (6.6)$$

which is the same as expression (1.2) presented earlier.

Therefore, to reckon any taper, one must first express it in the form of equation (6.1). By simple substitution, one determines $U = P-R$ and writes equation (6.6) directly. For instance, for body cut A to B in Figure 5(a), from equation (2.2) and (2.3), we have:

$$14 \text{ steps} = \left[\begin{matrix}4\\ \text{points}\end{matrix}\right]\left[\begin{matrix}3\\ \text{steps}\\ \text{per}\\ \text{point}\end{matrix}\right] + \left[2 \text{ steps remainder}\right] \quad (7.1)$$

which is the initial form (6.1). One now finds $U = P-R = 4-2 = 2$ points.

Therefore,

$$14 \text{ steps} = \left[\begin{matrix}2\\ \text{points}\end{matrix}\right]\left[\begin{matrix}3\\ \text{steps}\\ \text{per}\\ \text{point}\end{matrix}\right] + \begin{matrix}2\\ \text{points}\end{matrix}\left[\begin{matrix}4\\ \text{steps}\\ \text{per}\\ \text{point}\end{matrix}\right] \quad (7.2)$$

which is in the general form (6.6). Any taper may be expressed in this way. Basically, to determine a taper, one must know m and n. Then one can write the taper in the general form of equation (6.1), and by a simple substitution, (finding $U = P-R$) write the taper in final form (6.6).

For the sake of brevity, let us agree to describe a taper going a whole mesh distance, where m and n are both whole numbers, as "condition BB" (for black to black) and a taper going a half mesh distance, where m and n are both whole numbers plus one half, as "condition BR" (for black to red).

To further illustrate the use of general formula (6.6) in the reckoning of tapers, consider body cut A to B in Figure 6. For this cut, $n = 21$ and $m = 7$, with "condition BB,"

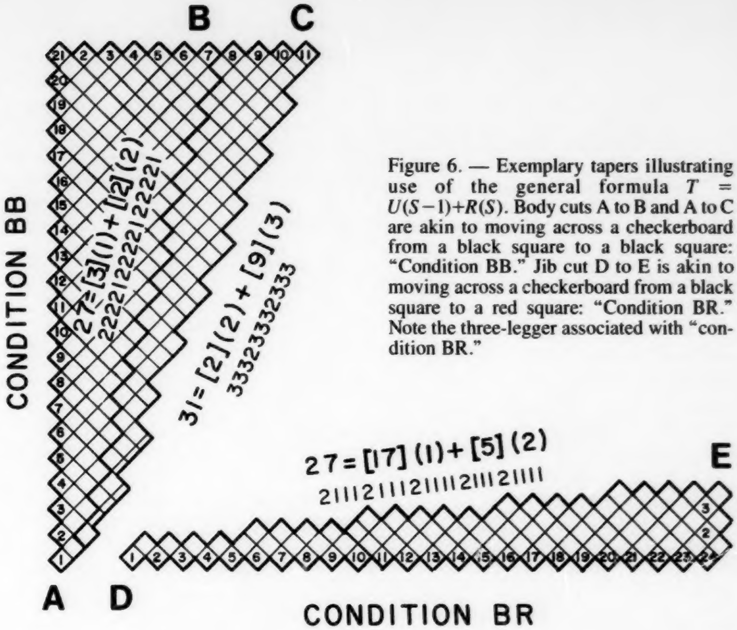


Figure 6. — Exemplary tapers illustrating use of the general formula $T = U(S-1)+R(S)$. Body cuts A to B and A to C are akin to moving across a checkerboard from a black square to a black square: "Condition BB." Jib cut D to E is akin to moving across a checkerboard from a black square to a red square: "Condition BR." Note the three-legger associated with "condition BR."

$$T = n+m-1 = 21+7-1 = 27 \text{ total steps} \quad (8.1)$$

and

$$P = n-m+1 = 21-7+1 = 15 \text{ points.} \quad (8.2)$$

From equation (6.1), we now write:

$$27 = (15)(S-1)+R. \quad (8.3)$$

The largest whole number to divide 27 by 15 is $(S-1) = 1$, so

$$27 = (15)(1)+R, \quad (8.4)$$

and $R = 12$. Since $(S-1) = 1$, $S = 2$.

And, $U = P-R = 15-12 = 3$, (8.5)

then $27 = (3)(1)+(12)(2)$ (8.6)

which is in the general form of equation (6.6). This expression implies a sequence 2, 2, 2, 2, 1, 2, 2, 2, 2, 1, 2, 2, 2, 2, 1 as illustrated in Figure 6. Note in expression (8.6) that there is a common factor, 3, of U and R:

$$27 = (3)(1)+(12)(2) = 3\left[(1)(1)+(4)(2)\right] \quad (8.7)$$

By finding a common factor, one can express the taper as a repeat pattern. Again in Figure 6, for the body cut A to C,

$n = 21$, $m = 11$, with "condition BB,"

$$T = n+m-1 = 21+11-1 = 31 \text{ total steps,} \quad (9.1)$$

and

$$P = n-m+1 = 21-11+1 = 11 \text{ points.} \quad (9.2)$$

From equation (6.1) we now write

$$31 = (11)(S-1)+R. \quad (9.3)$$

The largest number to divide 31 by 11 is $(S-1) = 2$, so

$$31 = (11)(2)+R \quad (9.4)$$

and, $R = 9$. Since $(S-1) = 2$, $S = 3$.

And, $U = P-R = 11-9 = 2$. (9.5)

Then $31 = (2)(2)+(9)(3),$ (9.6)

which is the general form of equation (6.6). Note that here 2 and 9 have no common factors. The taper could be expressed as 3, 3, 3, 2, 3, 3, 3, 2, 3, 3, 3 as illustrated in Figure 6.

At this point one can express any taper in the general form of equation (6.6). As was seen in the preceeding example of Figure 6, body cut A to B, a common factor existed, 3, which simplified specifying the numerical sequence. In body cut A to C, no common factor existed.

To reckon a taper, after expressing it in the general form of equation (6.6), one looks for a common factor of U and R. One could rewrite general equation (6.6) as:

$$T = F\left[(U')(S-1)+(R')(S)\right], \quad (10.1)$$

where F is a common factor of U and R, such that $U = F \times U'$ and $R = F \times R'$.

Once the taper is expressed in this form, as it was in equation (8.7), the sequence is usually determined by inspection and written directly. If, for example, one had determined a general form expression of

$$335 = (40)(4)+(35)(5), \quad (10.2)$$

one could factor out a 5, which is a common factor of 40 and 35 so that

$$335 = 5\left[(8)(4)+(7)(5)\right], \quad (10.3)$$

which is in the form of equation (10.1) above. Therefore, there are 5 repeats of the pattern: 4, 5, 4, 5, 4, 5, 4, 5, 4, 5, 4, 5, 4, 5, 4.

When U' and R' of equation (10.1) are large numbers, it is sometimes difficult to write the sequence by inspection. Suppose one had the final expression

$$540 = 20\left[(17)(1)+(5)(2)\right]. \quad (10.4)$$

To arrange a sequence of seventeen 1's and five 2's by inspection takes a bit of numerical juggling. However, an explicit procedure is available using ordinary graph paper. If one sets up a regular Cartesian coordinate system with U' and R' plotted as, respectively, abcissas and ordinates, the correct sequence can be specified by writing S or $S-1$ in the order by which the graph lines are crossed on the line connecting U' and R' (on their respective axes). This process is illustrated in Figure 7(a). Note that $U' = 17$ and $R' = 5$ have been plotted respectively as abcissas and ordinates, and a line $U'R'$ has been drawn between them. Note also that along the line, each time it crosses a graph line, a 1 or 2 is written depending on whether it crossed a vertical or horizontal line. In this case we have: 1, 1, 1, 1, 2, 1, 1, 1, 2, 1, 1, 1, 1, 2, 1, 1, 1, 2, 1, 1, 1, 2.

By letting $F = 1$, this sequence is illustrated in jib cut D to E in Figure 6. (I have drawn the sequence starting with a "2", that is, by reading the above sequence from right to left, so as to avoid starting the taper with four single meshes.) Note that taper D to E represents "condition BR." In Figure 7(b) another example is presented. Consider the following taper:

$$226 = 2\left[(7)(4)+(17)(5)\right]. \quad (10.5)$$

The "graph paper technique" in this case yields two repeats of the sequence: 4, 5, 5, 4, 5, 5, 4, 5, 5, 5, 4, 5, 5, 4, 5, 5, 5, 4, 5, 5, 4, 5, 5, 5. To cut such a taper in real webbing without making a mistake somewhere would be an endurance contest at best. In practice, it would probably be advisable to modify the net plan somewhat to avoid such a complicated sequence. In any event, the graph paper technique works well enough and could easily be expressed as an algorithm suitable for inclusion in a computerized routine. (Refer to subroutine ORDER, described in Martin and Recksiek (1983).)

Cutting Out Trawlnet Sections

So far we have discussed the process of describing tapers as determined by whole-number arithmetic expressions. At this point, methods of shaping some specialized trawlnet sections will be presented. I do not intend to cover procedures for most possible net sections; rather, by detailing an approach to certain specific types, I leave it to the readers to devise their own methodology for their special needs. In particular, I will discuss the trapezoidal shapes of squares and bellies, and some quadrilateral wing shapes. All equations used in this topic area are summarized in Table 1.

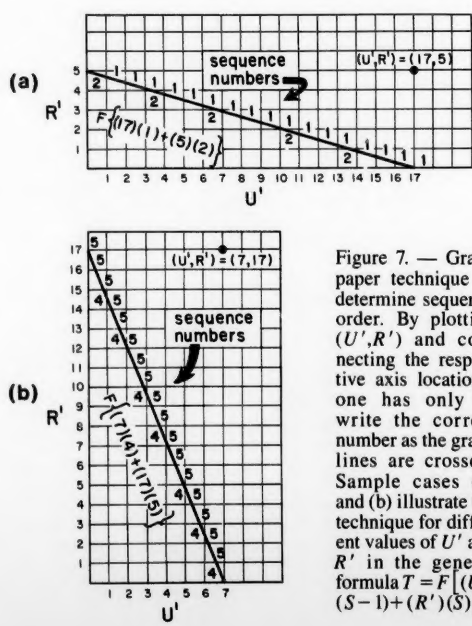


Figure 7. — Graph paper technique to determine sequence order. By plotting (U',R') and connecting the respective axis locations, one has only to write the correct number as the graph lines are crossed. Sample cases (a) and (b) illustrate the technique for different values of U' and R' in the general formula $T = F\left[(U')(S-1)+(R')(S)\right]$.

The primary motivation for this section is to aid the net planner. By being given certain section dimensions in numbers of meshes, the net planner must be able to correctly determine the taper (the number sequence). A secondary but very important motivation in this presentation is to cut the webbing so waste is minimal. Thus the ensuing discussion will continually stress procedures for making the most of the available webbing.

Squares, Bellies and Extensions

A square, belly, or extension section of a trawlnet is in the shape of a trapezoid. The cutting procedure is illustrated in Figure 8 for "condition BR" and "condition BB." Also illustrated are small trapezoids which represent the sections on a net plan.

The net plan will give us the dimension of the section in terms of meshes. Let k = meshes along the narrow end, t = meshes along the wide end, and n = meshes deep.

The basic procedure is to start with a rectangular piece of webbing, cut off a tapered piece, and sider it to the other

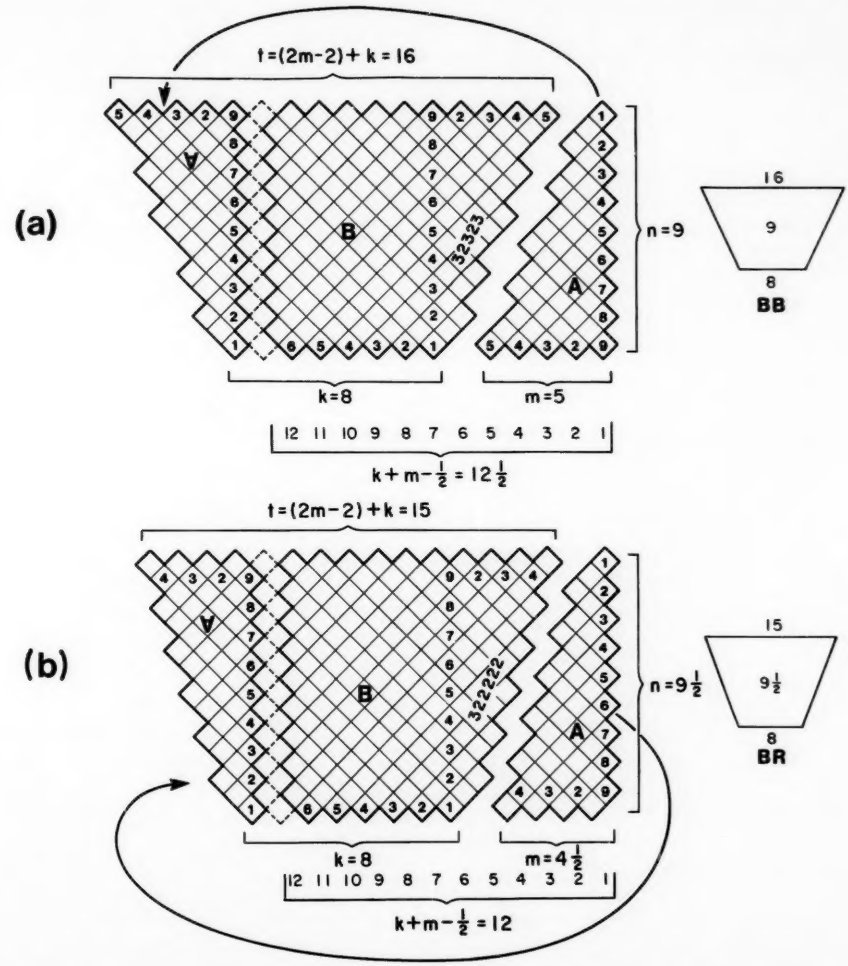


Figure 8. — Exemplary trapezoidal square, belly, or extension sections. Net plans and cutting procedure are illustrated for sections for (a) "condition BB" and for (b) "condition BR." The section dimensions are given as: t, meshes across top or wide end; k, meshes across bottom or narrow end; n, meshes deep. Arrows indicate how webbing piece A is cut away from the rectangular parent piece (yielding B) to be sidered onto the other side of B to form the finished section.

side. The arithmetic involves using k, t, and n to determine m. Both n and m are as defined previously. These are then used to find the tapering expression (6.6) as also illustrated. Once the taper is determined, it only remains to cut out two tapered pieces from a single rectangular parent piece, reorient them, and sider them back together. The process is illustrated in Figure 8.

At this point the importance of recognizing a taper as "condition BB" or "condition BR" becomes clear. In "condition BB" the net builder must cut two three-leggers into one edge of the original piece, whereas in "condition BR" piece A and piece B each have their own three-legger. Study of Figure 8 should make the distinction clear to the reader.

Let us now go through the calculations required for "condition BB" for a section having dimensions $t = 16$, $k = 8$, and $n = 9$. The process is illustrated in Figure 8(a). The first step is to determine m by a specialized "belly top" equation,

$$t = (2m-2)+k. \qquad (11.1)$$

Substituting our values into this formula we have,

$$16 = (2m-2)+8 \qquad (11.2)$$

or, $m = 5$.

Since $n = 9$,

$$\frac{T}{P} = \frac{n+m-1}{n-m+1} = \frac{9+5-1}{9-5+1} = \frac{13}{5}\cdot \qquad (11.3)$$

In the form of equation (6.1) we have,

$$13 = (5)(2)+3. \qquad (11.4)$$

This reduces to the final form of equation (6.6) as:

$$13 = (2)(2)+(3)(3) \qquad (11.5)$$

or a sequence of 3, 2, 3, 2, 3 as shown in Figure 8(a).

One cuts the tapers, from opposite directions, to leave pieces A and B. Piece A is slid around and sidered back onto B to form the finished section. Three-leggers on the left side of the original piece of webbing permit easy sidering back together. A final point is that the original rectangular piece of webbing had dimensions $(k+m-½) = 8+5-½ = 12½$ meshes by $n = 9$ meshes. Therefore, knowledge of m is not only necessary for correct tapering but for selection of an original piece of the correct minimum size.

The calculations and methodology for Figure 8(b) "condition BR" are similar to those just described. Given that $t = 15$, $k = 8$, and $n = 9½$, substituting these values into the specialized "belly top" formula (11.1) we have,

$$15 = (2m-2)+8 \qquad (12.1)$$

or, $m = 4½$. The fact that m is not a whole number confirms that the taper represents "condition BR." So, with $m = 4½$ and $n = 9½$,

$$\frac{T}{P} = \frac{n+m-1}{n-m+1} = \frac{9½+4½-1}{9½-4½+1} = \frac{13}{6}\cdot \qquad (12.2)$$

In the form of equation (6.1) we have,

$$13 = (6)(2)+1. \qquad (12.3)$$

This reduces to the final form of equation (6.6) as:

$$13 = (5)(2)+(1)(3) \qquad (12.4)$$

or as a sequence of 3, 2, 2, 2, 2, 2 as shown in Figure 8(b). Just like "condition BB," one cuts two tapers from opposite directions. However, each new piece has its own three-legger. These three-leggers turn out to be in a correct location for sidering the pieces back together. A starting piece is required, having dimensions $(k+m-½)$ meshes by n meshes.

At this point the reader should note that in equation (11.1), m can take either 1) a whole number value or 2) a whole number plus one-half. In these examples, illustrated in Figure 8, m took exemplary values of 5 and 4½. It turns out that for "condition BB" belly sections, n and m are both whole numbers, whereas for "condition BR" belly sections, neither n nor m are whole numbers. This consideration becomes important when following a net plan. Such a plan may specify n, t, and k. If n is fractional, m, as determined by equation (11.1) must be fractional. If n is a whole number, m must be a whole number. If these conditions are not met, the section will lack symmetry. That is, the taper on one side cannot be the same as the taper on the other side. In actual practice, one would simply calculate m from equation (11.1). If both n and m were either fractional or not fractional, the net plan would need readjustment. (Refer to Figure 1, note 4, of Martin and Recksiek (1983) where net plan belly dimensions are subjected to a test for symmetry.)

A similar situation to that just described for Figure 8 is illustrated in Figure 9. Here two identical sections are cut from one rectangular piece of webbing. The dimensions of the finished sections are the same as those illustrated in Figure 8. Note that the dimensions of the original piece are $2(m+k)-½$ meshes by n meshes.

Trawl Wings

Figure 10 illustrates the cutting out of a pair of "condition BB" wings from a single rectangular piece of webbing. The wing has one side cut all bars. Note that n is the depth, 12 in this example. Letting $e = 11$, and $k = 18$ for the respective dimensions of narrow and wide ends, m is determined by a "wing" formula:

$$e = (k-n)+m. \qquad (13.1)$$

Substituting values into this formula we have

$$11 = 18-12+m \qquad (13.2)$$

or, $m = 5$

and, therefore,

$$\frac{T}{P} = \frac{n+m-1}{n-m+1} = \frac{12+5-1}{12-5+1} = \frac{16}{8}\cdot \qquad (13.3)$$

This reduces to the final form of equation (6.6) as: $16 = (8)(2)$ or a sequence of 2, 2, 2, 2, 2, 2, 2, 2. The rest of the operation is as illustrated in Figure 10.

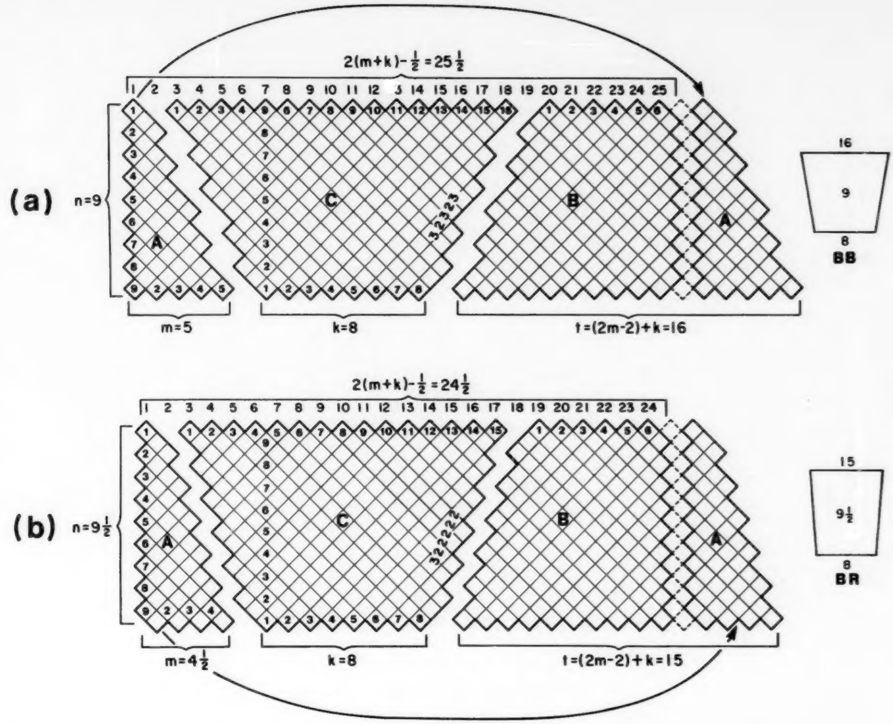


Figure 9. — Trapezoidal net sections illustrating the shaping of two finished identical pieces from the same rectangular piece of webbing. Net plans and cutting/fitting procedures are illustrated for (a) "condition BB" and for (b) "condition BR."

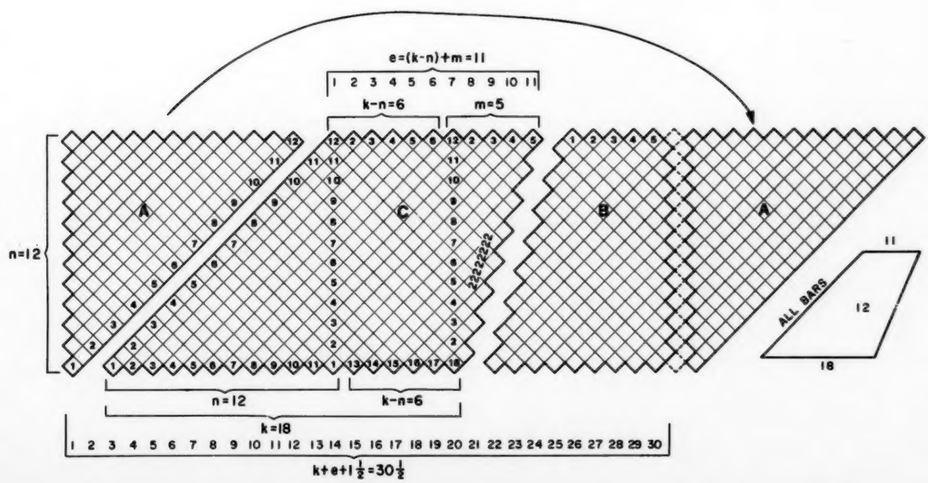
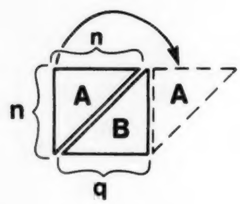


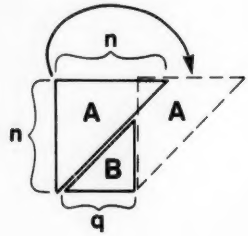
Figure 10. — Exemplary "condition BB" wing section assembly with net plan specifying wing dimensions.

The original webbing measured $(e+k+1\frac{1}{2})$ meshes by n meshes.

Practical difficulties may arise in cutting off a corner and sidering it onto the other end to form a parallelogram as was illustrated in Figure 10. There is a limit to the dimension of the top edge (or the side edge, n, which is the same) which must be considered. In the following diagram, note that piece A exactly fits back against piece B. Note too that $n = q$. This turns out to be the limit on the dimension of n for doing this kind of fit.



In the next diagram, observe that an exact fit cannot be made without waste, and $n > q$.



In Figure 11, the maximum value of n to make simple fits is illustrated. In this instance the top and bottom edges of the parallelogram are equivalent to $e+k$ ($e+k$ can be likened to q in the above diagram). For "condition BB," a simple fit can be made if $(n+1) \leqslant (e+k)$. Figure 11(a) illustrates this. Figure 11(b) illustrates a maximum of n for "condition BR." Here, a simple fit can be made if $(n+\frac{1}{2}) \leqslant (e+k)$.

In both Figures 10 and 11, observe that the bottom dimension of the original piece of webbing is given by $(e+k+1\frac{1}{2})$.

Figure 12 illustrates one possible strategy in building a pair of "condition BB" wings when $(n+1) > (e+k)$. There are certainly various means available to achieve minimal waste, and this example is but one. Note again that the parent piece has a bottom dimension of $(e+k+1\frac{1}{2})$.

Referring to Figure 12, to illustrate finding the depth from the net diagram, let us suppose that this time we are given e, k, and the taper. These are respectively, 3, 9, and "4 bars 1 point plus six sets of 3 bars 1 point." This, in our system, translates to 5, 4, 4, 4, 4, 4, 4, or,

$$29 = (6)(4)+(1)(5). \qquad (14.1)$$

This is changed to the form of equation (6.1):

$$29 = (7)(4)+1. \qquad (14.2)$$

The problem now is to find the depth, n. By expressions (1.3) and (2.1) we have a system of two equations in two unknowns which is solved by summing:

$$\begin{array}{rcll} n+m-1 & = & 29 & (14.3) \\ +n-m+1 & = & 7 & (14.4) \\ \hline 2n & = & 36 & (14.5) \end{array}$$

or, $n = 18$. Note, too, that by solving expression (14.3) for m, we have $m = 12$. The piece can now be cut out and assembled.

Double tapers can also be made in wing sections. Figure 13 illustrates the forming of a double wing taper from a single rectangular piece of webbing. The net plan must specify e, k, and a taper along one edge. The problem is to reckon the second taper. To do this one uses a "double-taper wing formula" which is actually a generalization of formula (13.1):

$$e = (k-m_1)+m_2 \qquad (15.1)$$

$$\text{with } m_1 > m_2 \qquad (15.2)$$

where e and k are defined previously and m_1 and m_2 are horizontal mesh distances of the two tapers. The greater horizontal mesh distance, m_1, is associated with the taper closest to the diagonal. In expression (13.1), note that n plays the role of m_1 for the special case of cutting on the diagonal (all bars).

For example, in Figure 13(a) we are given $e = 7$, $k = 11$, the taper closest to the diagonal "four sets of 4B1P", or 5, 5, 5, 5, which translates to

$$20 = (4)(5). \qquad (15.3)$$

This is automatically in the form of equation (6.1) since $R = 0$, so by equations (1.3) and (2.1) we have

$$\begin{array}{rcll} n+m_1-1 & = & 20 & (15.4) \\ +n-m_1+1 & = & 4 & (15.5) \\ \hline 2n & = & 24 & (15.6) \end{array}$$

or, $n = 12$. Solving equation (15.4) for m_1, we find $m_1 = 9$. Substituting values for e, k, and m_1, into equation (15.1) we have

$$7 = (11-9)+m_2 \qquad (15.7)$$

so $m_2 = 5$.

Now the wings can be shaped. Piece A is cut away and sidered back onto the parent piece. The parent piece will be, as before, $(e+k+1\frac{1}{2})$ meshes along the bottom. After A and B are sidered back together the second taper can be cut. This is reckoned in the regular way:

$$\frac{T}{P} = \frac{n+m_2-1}{n-m_2+1} = \frac{12+5-1}{12-5+1} = \frac{16}{8} \qquad (15.8)$$

This reduces to the final form of equation (6.6) as:

$$16 = (8)(2). \qquad (15.9)$$

The tapers are now cut to form two identical wings, as in Figure 13(a). The "condition BR" example illustrated in Figure 13(b) is handled the same way. Here we are given $e = 5$, $k = 8$, and the taper closest to the diagonal "three sets of 4B1P plus 3B1P," or 5, 5, 5, 4.

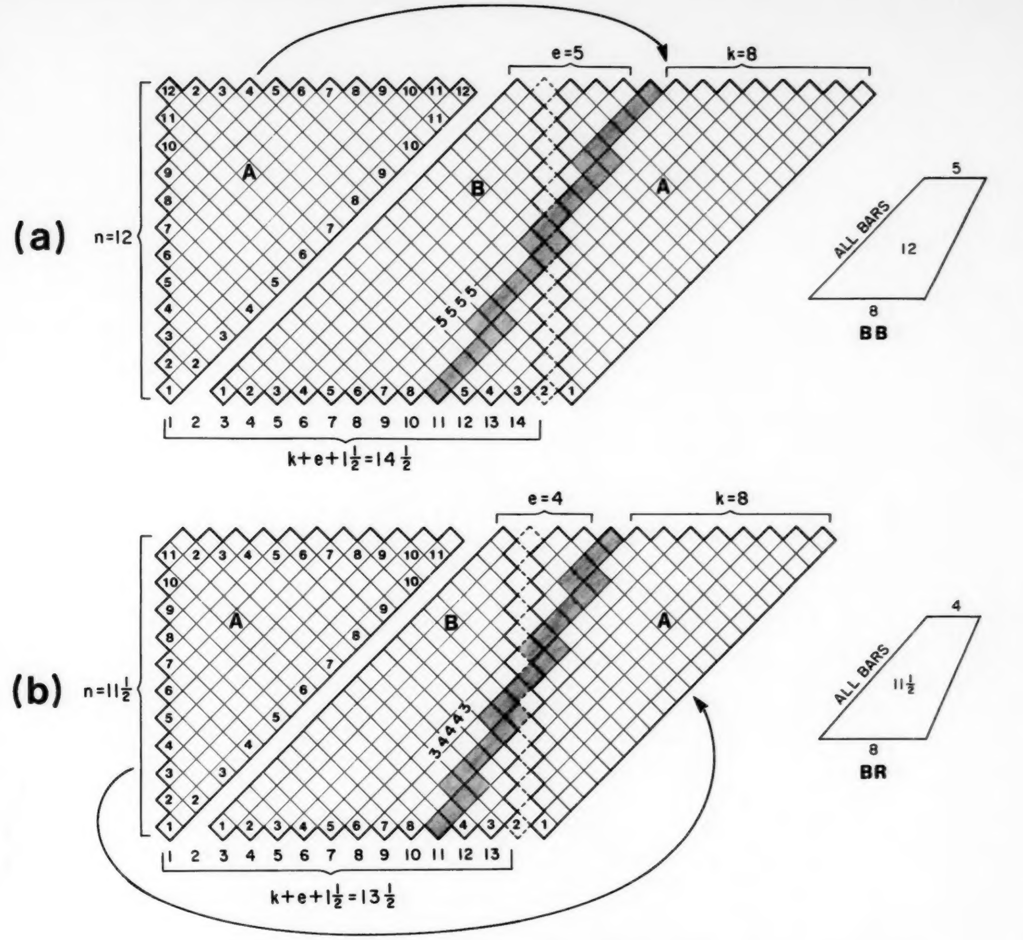
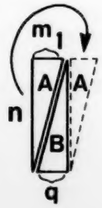
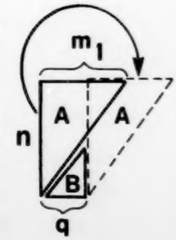


Figure 11. — Demonstration of the maximum value of n. (a) "Condition BB." In this case $(n+1) = (e+k)$. If $(n+1)$ exceeds $(e+k)$, the wing cannot be assembled this way. As with other examples, $(e+k+1½)$ meshes are required along the bottom of the parent piece. (b) "Condition BR." Here, $(n+½) = (e+k)$. If $(n+½)$ exceeds $(e+k)$, the wing cannot be assembled this way.

The remaining consideration is the difficulty which could be experienced when attempting to minimize waste by fitting from a single rectangular piece. In the following diagram, note that piece A fits exactly onto piece B; note also that $m_1 = q$; this turns out to be the limit on the dimension of m_1 for doing this kind of fit.



In the next diagram, $m_1 > q$ and the fit cannot be made this way without waste.



In light of previous discussions of fitting wings having one edge all bars, note that m_1 is taking the role of n in those earlier limits. The constraint, $(m_1+1) \leqslant (e+k)$, "condition BB," is therefore the general case and $(n+1) \leqslant (e+k)$ is a specific one for wings having

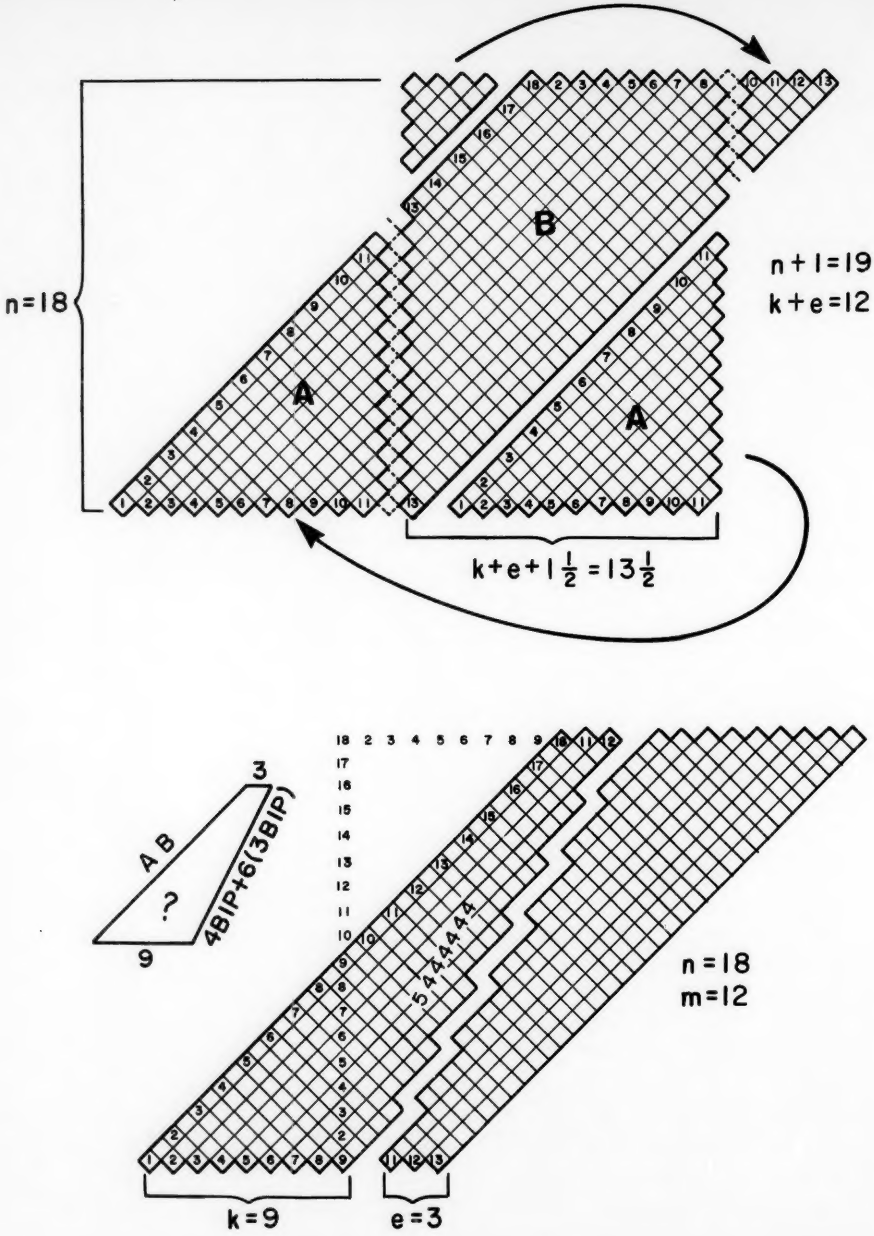


Figure 12.—Illustration of "condition BB" wing assembly when $(n+1) > (e+k)$. As with assembling wing sections using a single bar cut, $(e+k+1\frac{1}{2})$ meshes are required along the bottom. Note positions of three-leggers. Note the designation "4B1P+6(3B1P)" on the section plan. This is a shorthand for a taper of "4 bars 1 point plus six sets of 3 bars 1 point" or a tapering sequence of 5, 4, 4, 4, 4, 4, 4. For methodology of finding n knowing the taper, e, and k, see text.

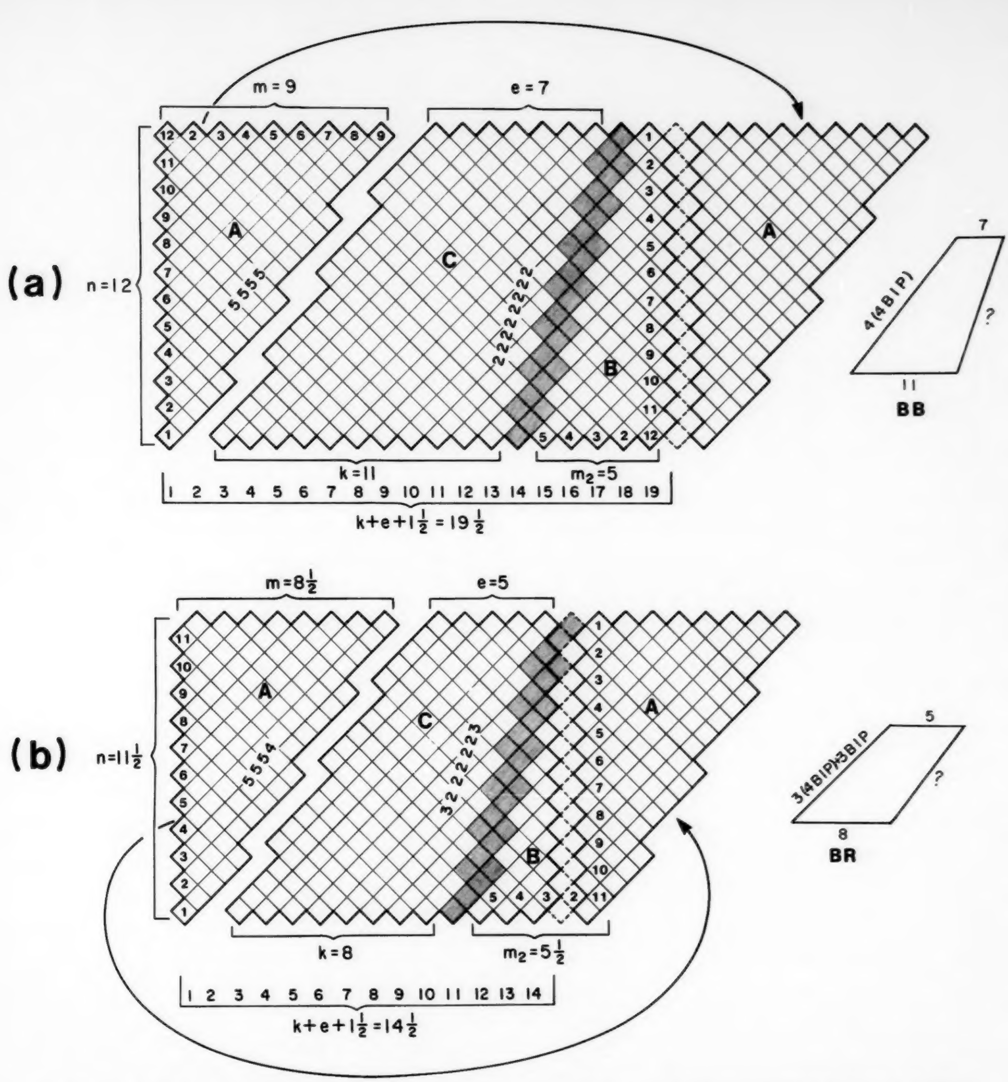


Figure 13. — Exemplary double wing tapers. In these cases the net plans give a taper along one edge. Piece A is taken off and sidered to the other side of the original piece of webbing. Then the second taper is cut across the joined piece to form pieces C and AB. Note that $(e+m_1) = (k+m_2)$. (a) Double taper, "condition BB." (b) Double taper, "condition BR."

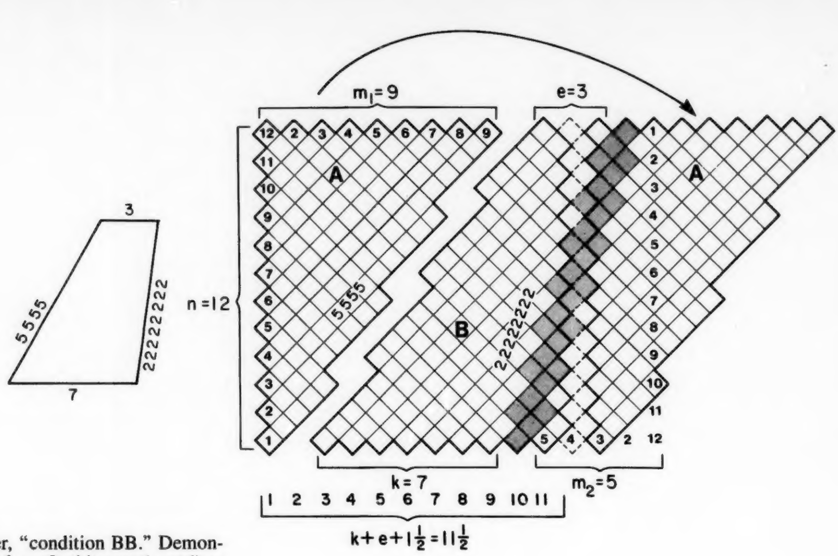


Figure 14. — Double wing taper, "condition BB." Demonstration of the maximum value of m_1. In this case $(m_1+1) = (e+k)$. If (m_1+1) exceeds $(e+k)$, the wing cannot be assembled this way. A strategy like that illustrated in Figure 12 is required. As with other examples, $(e+k+1½)$ meshes are required along the bottom of the parent piece.

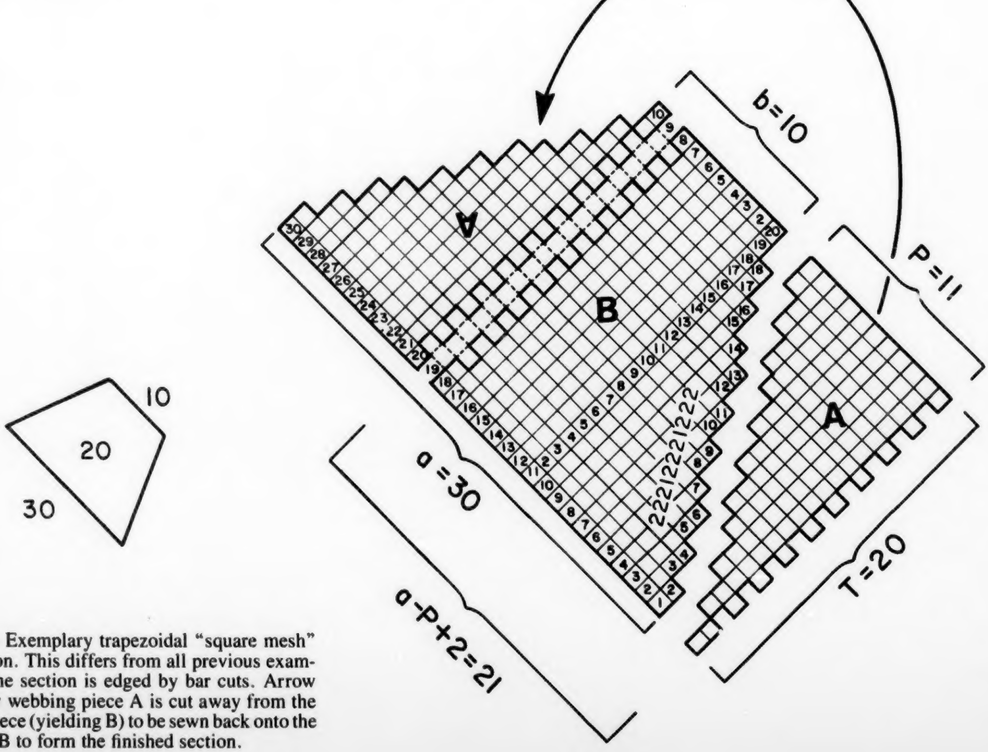


Figure 15. — Exemplary trapezoidal "square mesh" trap net section. This differs from all previous examples in that the section is edged by bar cuts. Arrow indicates how webbing piece A is cut away from the rectangular piece (yielding B) to be sewn back onto the other side of B to form the finished section.

one edge all bars. In Figure 14, "condition BB" wing tapers are presented with $(m_1+1) = (e+k) = 10$. For higher values of m_1, where $(m_1+1) > (e+k)$, the fits cannot be made as illustrated. A strategy like that illustrated in Figure 12 will be required.

Cutting Out Square Mesh Net Sections

One final consideration in applying the tapering principles presented here is that of a net section composed of "square meshes," as in a tennis net. Recent work by Robertson (1982) on square mesh codend design could be applied to net sections other than codends. Robertson's Figure 7 shows a trapezoidal upper codend section of square meshes. An example, a section from a Great Lakes trap net from Stewart and Visel[1], is pictured in Figure 15. In this case, letting $a = 30$ meshes along the wide end and $b = 10$ meshes along the narrow end, we have a shape like that of a trawl belly or extension section. The depth is given by $T = 20$ meshes. Note that the total number of steps required for the taper is equal to the depth (hence "T" as defined previously). The number of points, P, is given by a special square mesh belly formula:

$$P = (a-b)/2+1. \qquad (16.1)$$

Substituting values into this formula we have

$$P = (30-10)/2+1 = 11. \qquad (16.2)$$

In the form of equation (6.1), we have

$$20 = (11)(1)+9. \qquad (16.3)$$

This reduces to the final form of equation (6.6) as

$$20 = (2)(1)+(9)(2) \qquad (16.4)$$

or as a sequence of 2, 2, 2, 1, 2, 2, 2, 1, 2, 2, 2 as shown in Figure 15. Note that a starting piece having dimensions T meshes by $a-P+2$ meshes is required and that these dimensions are for webbing cut on the diagonal. The methodology of sewing the cut-off piece back onto the parent piece is similar to that of a belly section, the major difference being that it is done on the diagonal.

Conclusions

The cutting/assembling procedures for various net section types were each deduced by careful study of the problem at hand and applying the general tapering equations (1.3, 2.1, 6.1, 6.6, 10.1). Most tapering problems boil down to deducing m and n. The reader may wish to modify the numbering conventions and use accordingly modified equations.

Translation of the various equations into computer program algorithms is straightforward. The companion article "A microcomputer program for the calculation of a trawlnet section taper" (Martin and Recksiek, 1983), presents an example of that process for trapezoidal shapes.

Acknowledgments

I thank Marion McHugh for preparing the drawings. This research was supported by the Office of Sea Grant (National Oceanic and Atmospheric Administration, NA81AA-D-00073). This publication is Contribution number 2,143 of the Rhode Island Experimental Station.

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[1]Stewart, L., and T. Visel. 1980. A guide to the construction of trap nets (Great Lakes Bar Type). Stationary gear workshop draft, 13 p. University of Connecticut Marine Advisory Service, Marine Science Institute, Groton, CT 06340.

A Microcomputer Program for the Calculation of a Trawlnet Section Taper

DAVID K. MARTIN and CONRAD W. RECKSIEK

Introduction

In this paper we describe a computer program which enables the user to find the correct taper of a trawlnet belly or extension section, given the dimensions, in meshes, of wide end, narrow end, and depth.

Our purpose in this report is fourfold:

1) To illustrate how general principles of web shaping and assembly, as described in the companion article, "Shaping and assembling webbing" (Recksiek, 1983), can be expressed as functional computer program algorithms;

2) to describe the program logic, through the flowchart medium, so the readers, who may so desire, can create their own code in the computer language of their choice according to their particular hardware constraints;

3) to discuss the logic in a general context so the readers may expand the program described for other requirements, e.g., reckoning wing section tapers; and

4) to report in tabular format, actual code in a version of BASIC programming language used in an inexpensive microcomputer system.

We will first describe the microcomputer system we used. We will then illustrate the use of our program by showing how some exemplary problems are solved with the system. The figures consist of flowcharts of the main program and its subroutines, which are outlined in an accompanying text discussion. Finally, we present the actual program code as Table 1.

The notation and specialized terms used in this paper will be the same as those of Recksiek (1983). (Variables in this paper are always written in upper case since the system we used cannot display lower case characters.)

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The Microcomputer System

We chose a readily available, low-cost microcomputing system which, exclusive of the television monitor, can be purchased for under $200. We used a Timex-Sinclair TS 1000[1] having 1 K bytes of random access memory (RAM). Plugged into the small (17×17 cm) keyboard/computing hardware package is an expandable memory of 16 K bytes. (The expandable 16 K RAM pack is required for the application being described in this report.) An inexpensive cassette tape recorder is interfaced with the machine and the programs are stored on cassette tape. The system's television monitor can display 31 columns by 21 rows of characters.

Program Function: Some Examples

After turning on the machine and loading the program, the user is prompted for the dimensions of the piece of webbing. When these have been entered, the machine performs the various calculations. Then, selected variables along with the tapering sequence are displayed on the monitor screen. The first example is taken from Figure 8(a) of "Shaping and assembling webbing" (Recksiek, 1983):

	ENTER WIDE END	prompt line.
16		user entered 16; screen clears and,
	ENTER NARROW END	second prompt line.
8		user entered 8; screen clears and,
	ENTER DEPTH	third prompt line.
9		user entered 9; screen clears and,

WE=16 NE=8 DEPTH=9 output lines begin....

TAPER IS STEPS/POINTS

TSTEPS=13 P=5 S=3 R=3 U=2
(RPRI=3 UPRI=2 F=1)

TAPER EQUAL TO: 3 2 3 2 3	final output line.

The next example is from Figure

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

8(b) of Recksiek (1983). Here, note that the user has input 10 for the depth, N. The user also has input T = 15 and K = 8. A belly section of these dimensions cannot be symmetric, i.e., the taper cannot be the same on both sides. The program executes a test for symmetry. We structured the program to revise the input depth in this circumstance so that dimensions of a symmetric piece could be displayed:

ENTER WIDE END	prompt line.
15	user entered 15; screen clears and,
ENTER NARROW END	second prompt line.
8	user entered 8; screen clears and,
ENTER DEPTH	third prompt line.
10	user entered 10; screen clears and,
WE=15 NE=8 DEPTH=9.5	output lines begin showing revised DEPTH;
SUBTRACTED 1/2 MESH FROM DEPTH	message signaling change....

TAPER IS STEPS/POINTS

TSTEPS=13 P=6 S=3 R=1 U=5
(RPRI=1 UPRI=5 F=1)

TAPER EQUAL TO: 2 2 2 2 3 2	final output line.

The program has the capability to deal with pieces having all bar edges or jib cut edges. The following example illustrates output for a piece having an all bar edge. The input lines have been omitted for the sake of brevity:

WE=18 NE=7 DEPTH=6.5	output lines begin....

TAPER IS A STRAIGHT BAR

TSTEPS=12 P=1 S=13 R=0 U=1
(RPRI=0 UPRI=1 F=1)

TAPER EQUAL TO: 12	final output line.

In the next example, the program

Table 1.— BASIC symbolic language code for computer program designed to generate a number sequence which represents a webbing taper for a trapezoidal section.

```
1000 REM "BELLY"
1005 REM MAIN PROGRAM FOR SQUARES, BELLIES
     AND EXTENSIONS
1010 REM
1020 PRINT AT 10,8; "ENTER WIDE END"
1030 INPUT T
1035 REM "CLS" MEANS CLEAR SCREEN ONLY
1040 CLS
1050 PRINT AT 10,7; "ENTER NARROW END"
1060 INPUT K
1070 CLS
1080 PRINT AT 10,10; "ENTER DEPTH"
1090 INPUT N
1100 CLS
1110 LET M = ((T - K)/2) + 1
1120 IF M = INT M THEN GO TO 1150
1130 IF N = INT N THEN GO TO 1160
1140 GO TO 1180
1150 IF N = INT N THEN GO TO 1180
1160 LET N = N - (0.5)
1170 PRINT AT 3,1; "SUBTRACTED 1/2 MESH FROM
     DEPTH"
1180 PRINT AT 1,2; "WE="; T; "NE="; K;
     "DEPTH="; N
1190 IF N = M THEN GO TO 1250
1200 IF N > M THEN GO TO 1270
1210 PRINT AT 5,5; "TAPER IS STEPS/MESHES"
1220 LET M2 = N
1230 LET N2 = M
1240 GO TO 1300
1250 PRINT AT 5,4; "TAPER IS A STRAIGHT BAR"
1260 GO TO 1280
1270 PRINT AT 5,5; "TAPER IS STEPS/POINTS"
1280 LET M2 = M
1290 LET N2 = N
1300 LET TSTEPS = N2 + M2 - 1
1310 LET P = N2 - M2 + 1
1320 LET S = (INT(TSTEPS/P)) + 1
1330 LET R = TSTEPS - ((S - 1) * P)
1340 LET U = P - R
1350 PRINT AT 7,1; "TSTEPS ="; TSTEPS; "P ="; P;
     "S ="; S; "R ="; R; "U ="; U
1360 LET AVALUE = S
1370 LET BVALUE = S - 1
1371 REM
1372 REM CALL RENAME SUBROUTINE
1373 REM
1380 GOSUB 4000
1390 LET UPRIME = U
1400 LET RPRIME = R
1401 REM
1402 REM CALL FACTOR SUBROUTINE
1403 REM
1410 GOSUB 5000
1420 PRINT AT 8,4; "(RPRI = "; RPRIME; "UPRI =";
     UPRIME; "F ="; F; ")"
1421 REM
1422 REM CALL ORDER SUBROUTINE
1423 REM
1430 GOSUB 6000
1435 REM CODE FROM HERE TO STATEMENT 1550 IS
     USED TO OUTPUT ARRAY S
1440 PRINT AT 13,0; "TAPER EQUAL TO:"
1450 LET H = 1
1460 LET V = 14
1470 FOR L = 1 TO KF
1480 PRINT AT V, H; SEQ(L)
1490 LET H = H + 2
1500 IF H = 31 THEN GO TO 1520
1510 GO TO 1540
1520 LET H = 1
1530 LET V = V + 1
1540 NEXT L
1550 STOP
4000 REM
4002 REM SUBROUTINE RENAME
4004 REM
4010 IF U < R THEN GO TO 4080
4020 LET X = R
4030 LET R = U
4040 LET U = X
4050 LET X = AVALUE
4060 LET AVALUE = BVALUE
4070 LET BVALUE = X
4080 RETURN
4090 REM
5000 REM SUBROUTINE FACTOR
5001 REM
5010 LET F = 1
5020 FOR I = 2 TO U
5030 IF UPRIME <= 1 THEN GO TO 5110
5040 IF (UPRIME/I) - INT(UPRIME/I) >< 0 THEN GO
     TO 5100
5050 IF (RPRIME/I) - INT(RPRIME/I) >< 0 THEN GO
     TO 5100
5060 LET UPRIME = UPRIME/I
5070 LET RPRIME = RPRIME/I
5080 LET F = F * I
5090 GO TO 5030
5100 NEXT I
5110 RETURN
5120 REM
6000 REM SUBROUTINE ORDER
6001 REM
6010 DIM A(200)
6020 DIM SEQ(300)
6030 LET INDEX = 0
6040 LET MF = UPRIME/RPRIME
6050 LET LASTR = RPRIME - 1
6060 FOR I = 1 TO LASTR
6070 IF INT(MF*I) = INT (MF*(I-1)) THEN GO TO
     6100
6080 LET INDEX = INDEX + 1
6090 LET A(INDEX) = BVALUE
6100 LET INDEX = INDEX + 1
6110 LET A(INDEX) = AVALUE
6120 NEXT I
6130 IF UPRIME = 0 THEN GO TO 6160
6140 LET INDEX = INDEX + 1
6150 LET A(INDEX) = BVALUE
6160 LET INDEX = INDEX + 1
6170 LET A(INDEX) = AVALUE
6180 LET KF = 0
6190 FOR I = 1 TO F
6200 FOR J = 1 TO INDEX
6210 LET KF = KF + 1
6220 LET SEQ (KF) = A (J)
6230 NEXT J
6240 NEXT I
6250 RETURN
```

identifies the taper as being a jib cut and the message, TAPER IS STEPS/MESHES, is displayed:

WE=18 NE=4 DEPTH=6	output lines begin....
TAPER IS STEPS/MESHES	
TSTEPS=13 P=3 S=5 R=1 U=2 (RPRI=1 UPRI=2 F=1)	
TAPER EQUAL TO: 4 5 4	final output line.

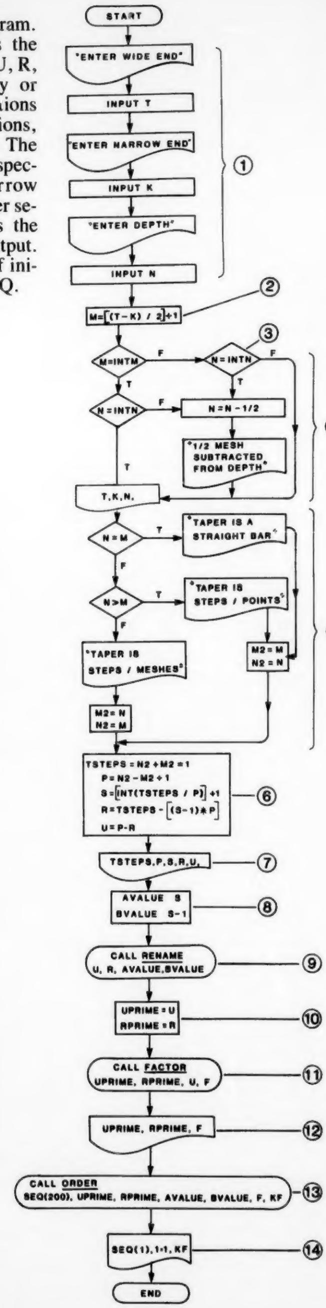

Figure 1. — Main program. This program calculates the various tapering values, U, R, S, F for trawlnet belly or extension-shaped net sections upon input of the dimensions, in numbers of meshes. The latter are N, K, T or, respectively, the "depth, narrow end, wide end." A number sequence which represents the taper is displayed as output. This sequence consists of initial elements of array SEQ.

Program Logic: A Flowchart

The logic used in the microcomputer program is portrayed in the figures. An expression of this logic in BASIC language code is presented in Table 1. This program code, when loaded into a Timex-Sinclair TS 1000 microcomputer system, produces the monitor displays described in the previous section.

Our intention in this section is to explain the flowchart so the prospective users can adapt the logic to serve their own ends. Basically, the logic parallels the theoretical development of Recksiek (1983). Readers are encouraged to thoroughly familiarize themselves with that article, particularly the introductory sections and the section, "Squares, Bellies, and Extensions."

As a matter of interest, we would like to mention that our preliminary coding of the flowcharted logic was accomplished in FORTRAN symbolic programming language on a mainframe computer. Our goal in that work, which is presently in progress, is to use that system's pen plotter to draw finished net sections. For the purpose of the application described in this article, we wrote the BASIC code directly from our FORTRAN code listing.

The program is structured as a main program module with three subroutines. We developed this structure with the potential user/programmer in mind. The main program can be easily modified to do other tasks, e.g., calculating wing tapers. This particular main program does the simple arithmetic of the "belly top formula" (equation (11.1) of Recksiek, 1983) and the general tapering equations.

The subroutines perform tasks which must be done by any program doing tapering calculations. These subroutines are called at critical points in the main program. In the following sections of this article, we summarize the functions of the various program modules.

Main Program

The main program calculates the various tapering values U, R, S, F for trawlnet belly or extension pieces upon input of the dimensions. The latter, expressed in numbers of meshes, are, respectively, N, K, T for "depth, narrow end, wide end." A number sequence which represents the taper is generated and displayed as output. This sequence consists of initial elements of an array, SEQ. The flowchart of this routine is presented in Figure 1. Referring to that figure, the following features are of interest:

1) Prompts and inputs of T, K, N.

2) Calculate horizontal mesh distance M as a function of T and K. This is equation (11.1), the "belly top formula" of Recksiek (1983).

3) Test of N being a whole number. (Other programming languages differentiating between real and integer variables may require some additional arithmetic.)

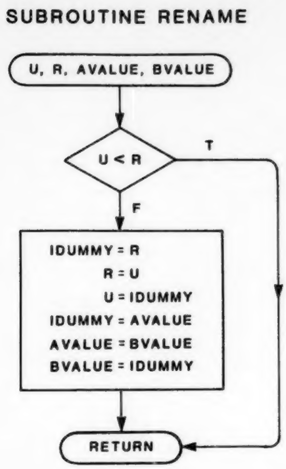

Figure 2. — Subroutine RENAME. Arguments: U, R, AVALUE, BVALUE. The subroutines FACTOR and ORDER require that arguments derived from U and R must be ordered one greater than or equal to the other. If the arguments are incorrectly ordered, the subroutine reverses their values.

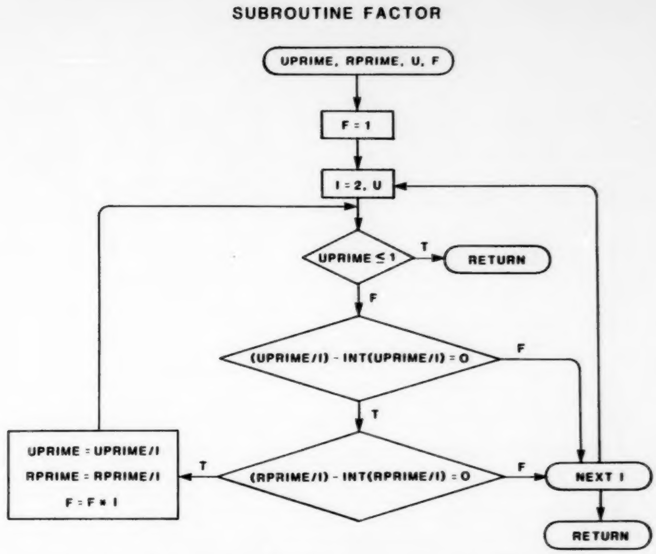

Figure 3.—Subroutine FACTOR. Arguments: UPRIME, RPRIME, U, F. This subroutine determines F, RPRIME, and UPRIME such that U = F × UPRIME and R = F × RPRIME. That is, F is the largest common factor of U and R.

4) Test of symmetry. If M contains a half mesh, then N must contain a half mesh. If M has no half mesh, then N must contain no half mesh. In other words, M and N must both be either whole numbers or both whole numbers plus a half mesh. In this logic, if the condition (both whole or both not whole) cannot be met, N is "adjusted" by subtraction of 0.5. As was illustrated earlier in the second problem example, the user is informed of this having taken place. This is a test of symmetry in that the tapers on both side edges of the piece must be the same.

5) The taper is a straight bar when N = M; it is a body cut, designated as "STEPS/POINTS," when N > M; it is a jib cut, designated as "STEPS/MESHES," when N < M.

6) Fundamental arithmetic. Calculation of TSTEPS (for total steps), P, S, R, U based upon principles embodied in equations (1.3) through (6.6) of Recksiek (1983).

7) Display of variables and calculated values.

8) AVALUE and BVALUE defined. These are arguments used in subroutines RENAME and ORDER. The subroutines FACTOR and ORDER require that arguments derived from U and R must be ordered one greater than or equal to the other. (The true values of U, R, and S are no longer of interest to the user by the time subroutine RENAME is called; hence they can be renamed to satisfy order requirements of the subroutines.)

9) Subroutine RENAME checks values of its arguments for correct relative size. Values are reversed, or "renamed," if necessary.

10) Arguments for subroutine FACTOR are defined.

11) Subroutine FACTOR determines F such that F is a factor common to U and R and that U = F×UPRIME and R = F×RPRIME.

12) Display of calculated values.

13) Subroutine ORDER determines the actual number sequence of the taper. Argument KF is the total number of nonzero elements of array SEQ, i.e., there are KF numbers in the sequence.

14) Display of sequence array SEQ.

Subroutine RENAME

Arguments: U, R, AVALUE, BVALUE. The subroutines FACTOR and ORDER require that arguments derived from U and R must be ordered one greater than or equal to the other. If the arguments are incorrectly ordered, this subroutine reverses their values (Fig. 2).

Subroutine FACTOR

Arguments: UPRIME, RPRIME, U, F. This subroutine determines F, RPRIME, and UPRIME such that U = F×UPRIME and R = F×RPRIME. That is, F is the largest common factor of U and R (Fig. 3).

Subroutine ORDER

Arguments: SEQ, UPRIME, RPRIME, AVALUE, BVALUE, F, KF. This subroutine generates KF nonzero elements of array SEQ such that each element represents one number in a tapering sequence. The reader is referred to Recksiek (1983) where equations (10.1) through (10.5) are discussed. That discussion includes a reference to the paper's Figure 7. This subroutine essentially performs the task embodied in that figure. Referring to Figure 4 in this paper, the following features are of interest:

1) Slope MF is determined by division. (This slope can be likened to examples illustrated in Figure 7 of Recksiek, 1983.)

2) Loop determines sequence, expressed as elements of primary array A, over the open interval UPRIME, RPRIME (but not over the closed interval UPRIME, RPRIME (see next step 3)). INDEX is the counter.

3) Last values of array A are determined for UPRIME and RPRIME. The highest and final value of INDEX is determined here. This program determines which of the two comes first in cut-and-dry fashion as shown in the flowchart. A person would make an "aesthetic" choice based, more or less, on the look of the taper. While this touch can probably be programmed, we thought the extra complication did not warrant the effort.

4) INDEX elements of array A are reproduced F times to produce the required sequence KF = F×INDEX elements of array SEQ.

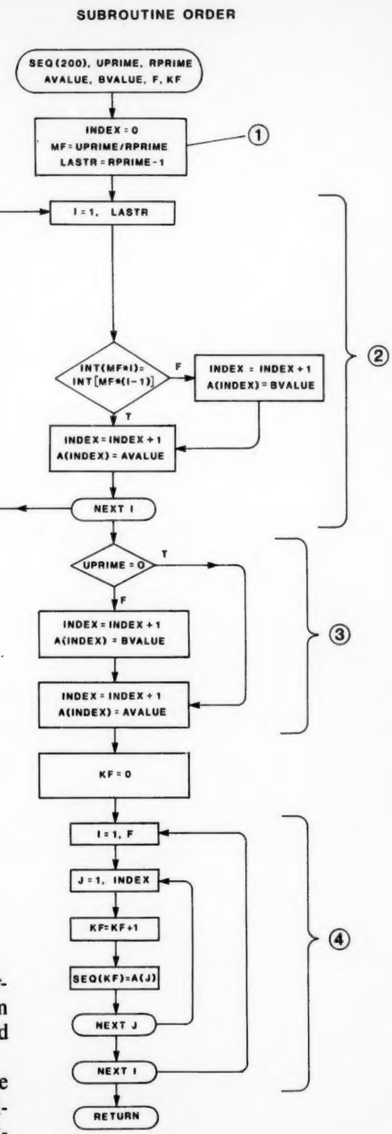

Figure 4.—Subroutine ORDER. Arguments: SEQ, UPRIME, RPRIME, AVALUE, BVALUE, F, KF. This subroutine generates KF nonzero elements of array SEQ such that each element represents one number in a tapering sequence.

Conclusions

The program described in this paper can be easily modified for other tasks. As mentioned earlier, the point of modification would be in the main program. For instance, the main program can be easily modified to reckon wing tapers.

The main program may be expanded to perform jobs other than, or in addition to, finding tapering sequences. For example, the user may wish to consider all dimensions of the piece, i.e., depth, wide end, narrow end, and taper, as being potential unknowns. On user-specified option, the program, given three dimensions, could find the desired but unknown fourth dimension.

Other capabilities could also be added. For example, hanging ratio calculations could be incorporated to reckon actual dimensions (for hanging the web onto headrope and fishing line, etc.). Or, twine weight parameters could be entered to estimate the amount of material actually required to construct the piece.

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Recent Developments in Papua New Guinea's Tuna Fishery

DAVID J. DOULMAN and ANDREW WRIGHT

ABSTRACT—This paper reviews Papua New Guinea's (PNG's) domestic (pole-and-line) and distant-water (purse-seine, longline, and pole-and-line) tuna fisheries from 1979 to 1982 and updates previously published works. The live-bait dependent domestic fishery, PNG's sixth largest export earner, landed 26,944 t of predominantly skipjack tuna, Katsuwonus pelamis, *during 1979, 34,099 t during 1980, and 24,029 t in 1981. The average annual value of these exports was $28.2 million. The reasons for the closure of the domestic fishery at the end of 1981 and its implications for future development are discussed.*

Distant-water fishing nation vessels operate in PNG's Declared Fishing Zone under negotiated Access Agreements. Japanese-based purse-seiners landed 12,906 t of tuna valued at $17.5 million during 1980 and 14,938 t valued at $18.0 million during 1981. Longliners landed 14,557 t valued at $31.0 million on the Japanese sashimi market during 1980 and 17,613 t valued at $35.0 million during 1981. Japanese long-distance pole-and-line vessels landed 503 t of tuna during 1979, 99 t during 1980, and only 16 t during 1981. These catches were valued at $134,177 in 1980 and $20,698 in 1981. The benefit PNG receives from these fisheries is analyzed and the likely future developments discussed, particularly with respect to regional cooperation through the Nauru Agreement.

Introduction

Like most island states in the central and western Pacific regions, the tuna resources found within the Papua New Guinea (PNG) 200-mile Declared Fisheries Zone (DFZ) represent an important resource. In PNG's case, its tuna resources, if fully developed, could be one of the nation's most valuable export industries.

The results of the recently completed Skipjack Tuna Assessment Programme conducted by the South Pacific Commission (SPC) infer that 180,000 metric tons (t) of skipjack tuna, *Katsuwonus pelamis*, can be taken annually from PNG's DFZ on a sustainable basis[1]. Total reported landings of skipjack tuna within PNG waters were approximately 42,000 t in 1980 and 31,000 t in 1981 which represent 23 percent and 17 percent, respectively, of the possible skipjack yield from the zone.

This paper reports and analyzes developments in PNG's tuna fishery from 1979 to 1982. In so doing, papers by Kearney (1975), Lewis and Smith (1977), Lewis[2], Wilson and Lindholm[3], and Wankowski and Lindholm[4] are updated. However, this paper represents the first attempt to relate economic and biological aspects of the fishery; previous authors dealt with biological aspects only.

PNG's tuna fishery has two components: The domestic fishery and the distant-water fishery. We begin with an analysis of the domestic fishery (including a production data review), the baitfishery, economic considerations, and reasons for the closure of the fishery at the end of the 1981 season.

Discussion of the distant-water fishery summarizes PNG's access arrangements with distant-water fishing nations (DWFN) since Independence in 1975. Fishery analysis focuses on the three fishing methods: Purse-seining, longlining, and pole-and-lining. Each method is reviewed in terms of available catch/effort and economic data. These data are in turn combined with data from the domestic fishery to provide an overview of PNG's tuna fishery as a whole.

The paper concludes by outlining PNG's view of the need for regional cooperation in the management of tuna stocks in the western Pacific and by commenting on future prospects for PNG's tuna fishery.

Domestic Fishery

Background

PNG's domestic commercial tuna fishery began in March 1970. This was after initial baitfish and tuna surveys in

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[3] Wilson, M. A., and R. Y. Lindholm. 1978. Papua New Guinea tuna and baitfish fishery: 1977. Fish. Div., PNG Dep. Primary Industry, Port Moresby, (mimeo), 12 p.

[4] Wankowski, J. W. J., and R. Y. Lindholm. 1980. The Papua New Guinea tuna and bait fisheries in 1978 and 1979. Fish. Div. Dep. Primary Industry, Port Moresby, (mimeo), 11 p.

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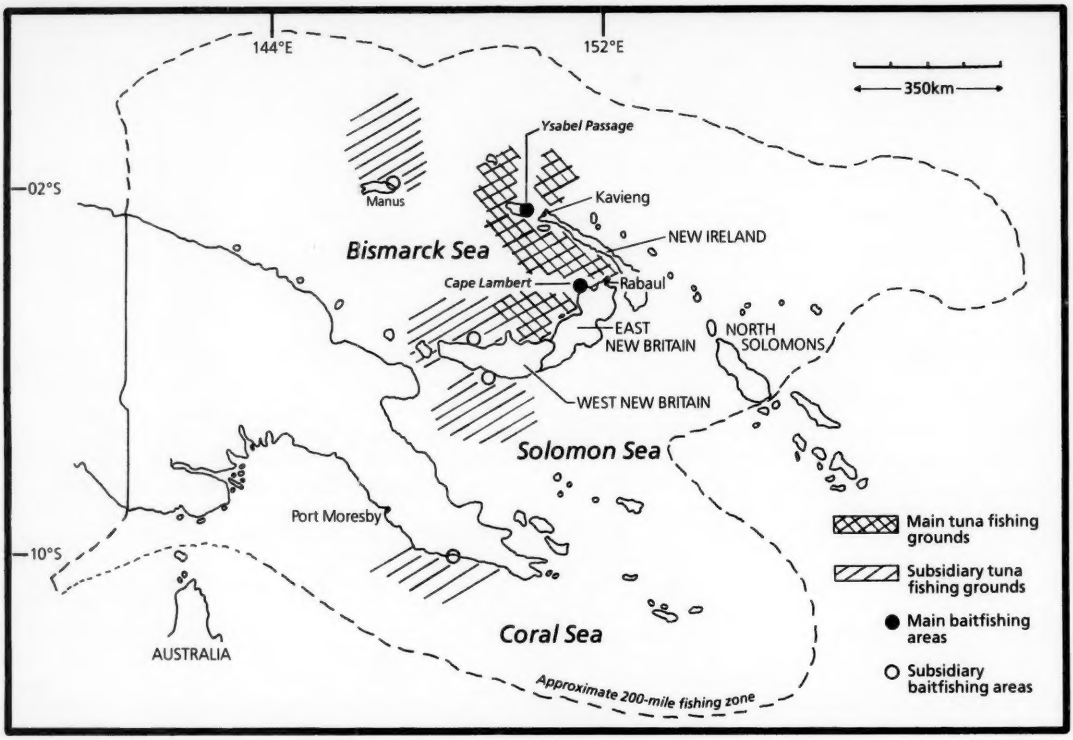

Figure 1. — Papua New Guinea baitfish and domestic tuna grounds.

the late 1960's indicated the existence of bait and tuna stocks capable of sustaining commercial exploitation (Anonymous, 1968; Nakamura, 1969). Two companies operated in the fishery in 1970, three in 1971, and four in 1972. However, by 1979 only two companies remained. These companies were Star-Kist (PNG) Pty. Ltd.[5] and New Britain Fishing Industries Pty. Ltd. (NBFI). Both companies operated through 1981, but as a result of deteriorating world tuna market conditions they did not start fishing in 1982. NBFI announced its intention to terminate operations in PNG due to losses incurred in 1981 and because of corporate reorganization plans by its parent company. Likewise, Star-Kist terminated its operations in PNG in early 1983.

Since the start, fishing operations have been primarily based around Kavieng in the New Ireland Province and more recently in the East New Britain Province adjacent to Cape Lambert because both areas have reliable supplies of good quality bait and are close to good tuna fishing areas. Other areas of PNG are also known to have good quality baitfish grounds but they have not been exploited extensively, either because there have been political problems over the opening of baitfish grounds to commercial exploitation or because the presence of tuna in these areas tends to be seasonal. Figure 1 shows PNG's proven tuna and baitfish grounds.

The pole-and-line method of fishing has been used exclusively in the fishery since 1970[6]. The boats employed were of the traditional Okinawan type. Most were 59 GRT class vessels, about 12 m long. Steel has replaced wood as the main hull material in more recent vessels. The main engines of these boats range from 350 to 600 hp with 50-150 hp auxiliary power units.

Despite attempts to establish shore bases, including a cannery, catcher boat

[5]Star-Kist (PNG) Pty. Ltd, is a wholly owned subsidiary of Star-Kist (California) Pty. Ltd, and part of the Heinz Group. New Britain Fishing Industries Pty. Ltd, is a subsidiary of Kaigai Gyogyo K.K. which in turn is owned by the Mitsubishi Corporation. Mention of trade names or commercial firms does not imply endorsement by the authors or by the National Marine Fisheries Service, NOAA.

[6]NBFI introduced a 400 GRT purse-seiner in late 1980 on a trial basis. The seiner made exceptionally good catches, but its operations were discontinued in mid-1982 because it proved uneconomic to operate a single seiner of this capacity.

operations from 1970 to 1981 used anchored motherships of 1,000-4,000 GRT. These vessels were moored close to the baiting grounds so that catcher boats could take on supplies and discharge their catch at the end of a day's fishing and prior to taking bait the same night. High mortality of bait in the catcher boats' holding tanks requires fresh supplies of bait to be obtained each night. Because of this, the operations of the domestic fishery have been highly localized as catcher boats were unable to fish more than 100 km away from motherships and baiting grounds.

About 10-12 catcher boats operate off each mothership. This constitutes one fishing unit. The four units that operated in 1981 were each valued at between $8 and $10 million[7], depending on the number of vessels, their age, and other considerations.

After the catch is transferred from the catcher boats to the mothership, it is brine frozen and stored below deck until sufficient supply has accumulated to require transshipment to a refrigerated carrier vessel. These carrier vessels call on demand to transport the catch to overseas markets. Almost the entire PNG catch since 1970 has been exported without being landed within the country[8].

Production

PNG ranked third as a world producer of skipjack tuna from 1971 to 1979, though on average the domestic fishery only produced 5 percent of the total world production each year (FAO, 1972-80). In the western Pacific region, as defined by FAO, PNG is by far the largest producer of skipjack tuna. The highest annual catch taken in the domestic fishery was 48,000 t in 1978. In 1979 the catch decreased to 26,944 t and averaged 28,357 t per year over the review period (Table 1). Fluctuations in resource availability, rather than changes in fishing effort or other factors, have resulted in the catch variation from year to year[9]. Fluctuations of this type are typical of all skipjack fisheries. However, they tend to be more pronounced at higher latitudes[10].

[7]All values are expressed in U.S. dollars.

[8]Between 1971 and 1978 Gollin Kyokuyo Pty. Ltd, operated a katsuobushi plant at Kavieng. The plant produced an average of 203 t of smoked tuna valued at $730,000/year for the Japanese market. The plant ceased operations in 1978 when the company terminated its involvement in the fishery.

Table 1. — Total catch, catch per fishing day, and number of boats in PNG's domestic tuna fishery, 1979-81.

Year	Catch (t) Total	Catch (t) Daily	No. of Boats[1]
1979	26,944	3.3	41
1980	34,099	3.6	43
1981	24,029	3.3	40
Mean	28,357	3.4	41

[1]Only vessels fishing for more than 50 days/year are included.

Source: Fisheries Division, PNG Department of Primary Industry, Port Moresby.

Table 2. — Distribution of catcher boat landings in PNG's domestic tuna fishery, 1979-81.

Catch per boat (t)	Number of boats 1979	1980	1981	Mean	Cumulative distribution (%)
<499	9	9	6	8	20
500 - 699	19	6	12	12	49
700 - 899	9	17	13	13	80
900 - 1,099	2	5	5	4	90
1,100 - 1,299	2	6	4	4	100
Total boats	41	43	40	41	

Source: Fisheries Division, PNG Department of Primary Industry, Port Moresby.

Catch per fishing day (cpue) in the fishery over the period under review ranged from 3.6 t on average per day in 1980 to 3.3 t in 1979 and 1981. The mean catch for this period was 3.4 t per day (Table 1). Catch rates, while fluctuating, have shown no tendency to decline since 1970. Consequently biologists believe these tuna stocks can sustain a higher level of fishing pressure than has been exerted in the past.

Between 1979 and 1981, an average of 41 boats operated on a full-time basis during each fishing season. Most boats do not fish during rough weather associated with the annual northwest monsoon season between December and March, although some NBFI boats did transfer their fishing operations to the relatively sheltered Papuan south coast during these months. The number of boats operating full time does not vary greatly from year to year (Table 1). However, there is a high degree of variation in the individual performance of boats within the fishery, in spite of all boats having access to the same or similar fishing grounds. Performance of boats is closely related to the fishing skills of the skipper, and in particular to the skills of the "mengane" (fish spotter) who directs the boat on the fishing grounds. It is also apparent from catch data that the performance of company-owned boats is inferior to skipper-owned and operated boats which are contracted by the companies[11].

[9]Our analysis of PNG catch data (unpubl.), supported by observations of fishing masters, indicates that good and bad fishing years alternate. The reasons for this are not known.

[10]Because of its proximity to the Equator, PNG is unique in that it has a year-round fishery. This is in contrast to Hawaii, Fiji, and New Zealand which have pronounced skipjack fishing seasons which usually coincide with summer months.

The distribution of catcher boat landings between 1979 and 1981 shows that on average 20 percent of the fleet took less than 499 t of tuna per year, while 49 percent landed less than 699 t (Table 2). Economic investigations have revealed that catcher boats need to take 800-850 t of tuna per annum at long-term average prices to operate at a break-even position. Thus the data contained in Table 2 shows that at least 50 percent of PNG's domestic fleet over the review period operated at a loss. This problem is exacerbated in years when prices fall below their long-term average trend. In the past, Star-Kist and NBFI have provided financial support to boats that were nonprofit operators with the result that some owners have become highly indebted to them. Only 10 percent of the catcher boats, on average, caught more than 1,100 t per year between 1979 and 1981[12]. Catches of more than 1,000 t per annum are required to ensure that a boat

[11]Star-Kist owns the Star of the Pacific fleet which in 1981 consisted of eight boats.

[12]The quality and adequacy of baitfish directly affects a boat's ability to catch tuna. If a boat is forced to take weak or unattractive bait, or is unable to secure sufficient quantities, it can be expected that its tuna catch rates will be below average. However, between 1979 and 1981 there is no evidence to suggest that some boats were unable to obtain sufficient supplies of good quality bait. Consequently, the variations in annual catches between boats appear unrelated to these factors.

Table 3. — Percent composition of catch in PNG's domestic tuna fishery, 1979-81.

Species	Catch composition (%)			
	1979	1980	1981	Mean
Skipjack tuna	89.0	90.8	85.4	88.4
Yellowfin tuna	10.7	8.9	14.6	11.4
Other	0.3	0.3	0	0.2
Total	100.0	100.0	100.0	100.0

Source: Fisheries Division, PNG Department of Primary Industry, Port Moresby.

Table 4. — Baitfish landings per day and bait-use effectiveness ratio in PNG's domestic tuna fishery, 1979-81.

Year	Bait (t)	Catch per day/ boat (buckets)[1]	Bait effectiveness (bait:tuna)
1979	1,424	69.6	1:18.9
1980	1,703	67.0	1:20.3
1981	1,473	70.0	1:16.3
Mean	1,533	68.9	1:18.5

[1]One bucket of bait equals 2.5 kg of fish.
Source: Fisheries Division, PNG Department of Primary Industry, Port Moresby.

is a nonmarginal operator.

The average operating cost of a typical 59 GRT pole-and-line boat in PNG's domestic fishery in 1981 was $565,000, though costs ranged from $384,000 to $728,000 for individual boats across the fleet. The major cost item for these boats was fuel which accounted for approximately 35 percent of the total operating costs. Crew costs (wages, travel, food, insurance, etc.) averaged 38 percent of total costs, and vessel costs (fuel, oil, maintenance, fishing gear, management fees, etc.) comprised the remaining 62 percent.

The total operating costs of the four motherships (NBFI = 1; Star-Kist = 3) were estimated to be $7.3 million. Costs ranged from $1.2 million to $2.3 million depending on the size of each vessel. Crew costs accounted for approximately 26 percent of total operating costs for each mothership while vessel costs were 74 percent of the total.

Average production costs for tuna in PNG's domestic fishery in 1981 were $1,148 per t. Of this amount, catcher boat costs represented 63 percent ($725/t), mothership costs 26 percent ($302/t), and shore-side costs 4 percent ($43/t). The remaining 7 percent ($78/t) was attributable to baitfish royalty payments, export tax, and other minor statutory charges. With a mean annual FOB price in 1981 of $1,040 (Table 6), it is estimated that an average of $108 was lost by the pole-and-line fleet for each metric ton of tuna landed.

The composition of the catch of the domestic tuna fishery for 1979-81 is shown in Table 3. Between these years skipjack tuna accounted for an average of 88.4 percent of the catch per year, yellowfin tuna, *Thunnus albacares*, 11.4 percent, and other species of tuna 0.2 percent. Skipjack tuna taken are in the 2-4 kg weight range and most yellowfin tuna weigh 6-9 kg.

Fish aggregating devices (FAD's) were introduced commercially in PNG's domestic fishery in 1981 by NBFI. A total of 56 devices were deployed, but losses were high due to devices breaking moorings in bad weather (DPI, 1982). Information gathered from tuna boat catch record data sheets about the use of FAD's in 1981 indicate that:

1) They are useful when tuna are scarce as there are always some fish available around them;

2) they are very productive when new schools of tuna are moving into the area where FAD's are anchored;

3) in general, the biting response of tuna around FAD's is best during the first hour after dawn; and

4) pole-and-line boats, due to their method of fishing, do not seriously deplete accumulated stocks of tuna under FAD's, which remain continuously productive. However, fishermen have indicated that purse-seining destroys tuna aggregations so that devices that have been fished by purse-seiners are usually left for about 1 month before being fished again.

Baitfishery

Unlike some states in the western Pacific, PNG has ample supplies of baitfish suitable for pole-and-line fishing[13]. The dominant species used are anchovies, *Stolephorus devisi* and *S. heterolobus*, and a sprat, *Spratelloides gracilis*. Biological aspects of PNG's baitfishery have been analyzed by Kearney (1977), Lewis (1977), Smith (1977), and Dalzell and Wankowski (1980).

Baiting is generally confined to two bait grounds, Ysabel Passage in New Ireland and Cape Lambert in East New Britain (Fig. 1). Baitfish landings from 1979 to 1981 averaged 1,533 t per year (Table 4). This represents a mean daily catch rate of 68.9 buckets of bait per boat per fishing day. Daily landings of bait at this rate probably exceed requirements for a normal day of fishing.

Fishermen tend to take excessive quantities of bait because the method of charging for it is not related to the quantity actually taken, but rather is tied to a fixed proportion of the value of tuna exports. Although this method of collecting payment for baitfish is administratively simple, it is fundamentally inadequate from a bait resource management point of view. PNG is currently reviewing its baitfishery policy and this aspect is being closely scrutinized.

Table 4 also shows a bait-use effectiveness ratio for the review period. The ratio (bait:tuna) ranged from 1:20.0 in 1980 to 1:16.3 in 1981 with a mean for the 3-year period of 1:18.5. As might be expected, bait tends to be used more effectively (i.e., tuna catches per unit of bait are higher) in good fishing years and less effectively in poorer fishing years. It is principally for this reason that the bait-use ratios in 1979 and 1981 are lower than in 1980.

While the relatively abundant supply of baitfish contributed to the rapid expansion of PNG's domestic tuna fishery in the early years of its development, the availability of bait rather than tuna is the limiting resource factor for the expansion of the domestic pole-and-line tuna fishery. The baitfishery has also proven to be a valuable management tool for the tuna fishery. In regulating the exploitation of the baitfishery through the control of access to baiting grounds, it has been possible to regulate indirectly and spatially distribute fishing effort within the tuna fishery.

Economic Considerations

The employment of nationals on catcher boats, motherships, and in

[13]This is partially due to PNG's large land masses and extensive river systems which together provide a constant supply of nutrients for baitfish in the sheltered waters adjacent to fishing grounds.

shoreside activities provides significant direct socioeconomic benefits to PNG. During 1979, 1,234 nationals were employed in all aspects of the fishery, 1,381 in 1980, and 1,202 in 1981 (Table 5). This represents a mean yearly employment figure for this period of 1,257. Of this total, 81.1 percent of nationals were employed on catcher boats, 14.8 percent on motherships, and 4.1 percent on shoreside activities. Overall, employment of nationals accounted for an average of 63.3 percent of the total employment in the fishery between 1979 and 1981.

Employment of foreigners in the fishery is also substantial. Between 1979 and 1981, an average of 730 foreigners were employed each year, 86.3 percent of which were employed on catcher boats.

The overall foreign:national employment ratio over the review period was 1:1.7. The ratios on motherships and shoreside (1:2.3 and 1:2.6, respectively) were noticeably higher than for the catcher boat ratio (1:1.6), primarily reflecting a higher degree of unskilled work (i.e., fish handling) on motherships and shoreside. However, it has been suggested by industry that the rate of national employment on catcher boats could be increased without affecting established production levels. Indeed, industry claims that for each catcher boat crew of 24, only 8 need be foreigners. Had this crew ratio been achieved, it would have lifted the mean catcher boat employment ratio between 1979 and 1981 from 1:1.6 to 1:2.0

An increased Papua New Guinea crew component could be expected to produce considerable savings for boat owners because of their lower rates of pay and bonuses. During 1981, the mean annual wage paid to nationals employed on catcher boats was $3,200, including bonuses. In comparison, mean wages and bonuses paid to Okinawans and Koreans employed in similar capacities were approximately $14,000 and $13,000, respectively. If an additional four positions on catcher boats are localized, wages and bonus savings per boat could be as high as $43,000 per year. Across a fleet of 40 boats these savings would exceed $1.7 million annually. Apart from the direct financial benefits to industry, the creation of additional employment opportunities for nationals would be viewed favorably by the PNG Government.

Table 5. — National and foreign employment in PNG's domestic tuna fishery, 1979-81.

	1979		1980		1981		Mean			Mean ratio
Category	Natl.	For.	Natl.	For.	Natl.	For.	Natl.	For.	Total	For.:Natl.
Catcherboats	943	574	1,150	700	1,012	616	1,020	630	1,650	1:1.6
Motherships	245	105	174	75	140	60	186	80	266	1:2.3
Shoreside	46	18	57	23	50	20	51	20	71	1:2.6
Total	1,234	697	1,381	798	1,202	696	1,257	730	1,987	1:1.7

Source: Star-Kist (PNG) Pty. Ltd. and New Britain Fishing Industries Pty. Ltd.

PNG's domestic tuna fishery ranks sixth as an export earner. Between 1979 and 1981 the value of these exports averaged $28.2 million (Table 6). This represents 74 percent of the value of PNG's fisheries exports over this period, 3 percent of the total value of exports and 2 percent of Gross Domestic Product. The highest value of exports from the domestic fishery in any year was $37.3 million in 1980.

Table 6. — Value of PNG's domestic tuna exports and mean FOB price per metric ton, 1979-81.

Year	Value of exports ($$10^6$)	Mean FOB price per ton ($)	U.S. west coast FOB price (all nations) ($)
1979	22.3	786	746
1980	37.3	1,080	1,162
1981	24.9	1,040	n.a.
Mean	28.2	969	954

Source: Bank of PNG, "Quarterly economic review," Port Moresby, and U.S. Department of Commerce, Washington, D.C.

Table 6 also compares PNG's mean annual FOB tuna price and the U.S. west coast mean annual skipjack tuna price. PNG's price rose from $786 in 1979 to $1,080 in 1980, easing to $1,040 in 1981. Over the period a mean price of $969 was recorded. A similar movement was registered in the U.S. west coast skipjack tuna price between 1979 and 1980, but the extent of the rise (55.8 percent) exceeded the increase in the PNG FOB price between these years (37.4 percent).

The U.S. market has traditionally been the largest market for PNG's tuna, followed by Japan. This is primarily because skipjack and smaller yellowfin tuna are most suitable for canning and the major canned tuna market is the United States. In 1979, 92.0 percent of PNG's domestic tuna catch was exported to the United States, either to the west coast, Puerto Rico, or American Samoa (Table 7). The proportion rose to 96.0 percent in 1980 but declined to 74.0 percent in 1981. This drop reflected the weakening U.S. market for tuna in 1981 combined with strengthening demand for good quality skipjack tuna in Japan.

Table 7. — Destination of exports from PNG's domestic tuna fishery, 1979-81.

Year	United States	Japan	Other
1979	92.0%	8.0%	
1980	96.0	4.0	
1981	74.0	22.0	4.0%
Mean	87.3	11.3	1.3

Source: Fisheries Division, PNG Department of Primary Industry, Port Moresby.

While it is recognized that skipjack tuna is an inferior sashimi fish compared with other tunas, Japanese industry officials have noted that its demand is rising because of its assured supply throughout the year and its predictable quality.

The market demand for canned tuna in Japan is also rising. This is reflected in the fact that exports of skipjack tuna from Japan to the United States were negligible in 1981 compared with the volume of exports in 1980. Between 1979 and 1981, the mean proportion of PNG's catch exported to the United States was 87.3 percent while the proportion going to Japan was 11.3 percent. Other destinations such as Australia, Singapore, and Mauritius took 1.3 percent.

Financial benefits accruing to the PNG Government through taxation and royalty payments to the baitfish owners

are detailed in Table 8. Export taxation payments between 1979 and 1981 averaged $1.4 million per year or 64 percent of total tax payments by the domestic tuna industry. Baitfish royalty payments averaged 29 percent of total payments or $616,611 per year. Total payments by industry to government and baitfish owners averaged $2.1 million per year over the review period.

Since the establishment of the domestic tuna fishery, no corporate income tax has been paid by any company. In addition, the two companies that operated in 1981 carried forward losses that would preclude the payment of corporate income tax even if profits were made in subsequent years. Consequently the main source of revenue for the national government was export tax. This tax is set at 5 percent ad valorem of tuna exports and does not apply to exports of processed tuna. The baitfish royalty is linked to the value of exports at the rate of 2.5 percent ad valorem.

Apart from direct financial benefits flowing from the domestic tuna fishery, indirect benefits accruing through linked industries were also substantial. Such expenditures by Star-Kist and NBFI in Rabaul amounted to $12-15 million yearly between 1979 and 1981[14].

Table 8. — Direct PNG National Government revenue and baitfish royalty payments from the domestic tuna fishery, 1979-81.

Revenue source	National Government revenue ($) 1979	1980	1981	Mean	Percent
Taxation					
Wages and salaries	94,315	91,708	103,963	96,662	5
Export	1,025,392	1,841,318	1,245,000	1,370,570	64
License fees	49,696	31,672	64,194	42,521	2
Subtotal	1,169,403	1,964,698	1,395,157	1,509,753	71
Baitfish royalties	512,568	920,659	416,608	616,611	29
Total revenue	1,681,971	2,885,357	1,811,765	2,126,364	100

Sources: Annual corporate statements of Star-Kist (PNG) Pty. Ltd. and New Britain Fishing Industries Pty. Ltd.

Closure in 1982

In early 1982 both Star-Kist and NBFI announced that their fishing operations would be suspended until the world tuna market improved. The closure of the fishery, which was not fully anticipated by the PNG Government, caused widespread unemployment and loss of foreign exchange, baitfish royalties, and taxation. The impact on linked industries (i.e., shipyards, merchants, and local farmers) has been dramatic. In most cases these industries have been forced to lay off workers either permanently or on a rotating basis. In 1982, the two Rabaul-based shipyards were operating with skeleton staff, approximately 80 percent below their scale of operations in 1981. These yards are so dependent on servicing the domestic tuna fleet that their survival has been jeopardized.

Doulman (1982) has summarized the reasons underlying the closure of the fishery. While world tuna production has risen significantly in recent years, principally from purse-seine operations in the western Pacific, the cyclical downturn in the tuna market which occurs every 3-4 years, has been exacerbated by the U.S. recession and prevailing high interest rates. The latter factor has forced canners to reduce inventories, thereby inflating supply at a time of flagging demand. Competition from such quasi-substitutes as hamburger, poultry, and other fishes, as well as cheap canned tuna from the Philippines, Taiwan, and Thailand, has dampened demand for tuna by U.S. processors.

The closure of the PNG fishery is also related in some degree to a movement by canners to disengage from fishing operations. With the contractual arrangements that have developed in recent years between fishermen and canners, especially in the United States, and the availability of fish on the world market, processors no longer require their own fleets to acquire fish for their canneries.

Distant-Water Fishery

Foreign vessels use three methods to exploit tuna within PNG's DFZ: Purse-seining, longlining, and pole-and-lining. PNG benefits from these operations only through the payment of access fees. These vessels do not enter PNG ports for provisions or to off-load their catch. This means that no PNG nationals are employed directly or indirectly in these fisheries. However, an intermediate goal of the PNG Government is to develop shore facilities to encourage foreign vessels to transship their catch at PNG ports. This would generate employment and related benefits.

Access Arrangements

Prior to PNG's independence, Australia was responsible for all foreign policy matters affecting PNG, including fisheries arrangements with DWFN's. Consequently, at Independence PNG inherited an access arrangement negotiated under a 1968 Australia-Japan Fisheries Agreement that gave Japanese vessels almost exclusive access to PNG waters. Under this pact, vessels were permitted to fish to within 3 miles of PNG's coastline. However, in 1976 PNG terminated this agreement and entered into a series of short-term ad hoc fisheries arrangements with the Government of Japan. These arrangements continued for varying periods until 1978.

In March 1978, PNG declared its 200-mile DFZ and the Governments of PNG and Japan formalized an Interim Fisheries Agreement for 9 months (May 1978-January 1979). Under this agreement, Japanese vessels wanting to operate in PNG waters paid annual vessel and fisherman fees of $43.50/m of vessel and $1.45 per crew member. These charges were made on a 3-month pro rata basis, the duration of each license period. In addition, a lump sum operational fee of $1.45 million was charged for all vessels. This fee was linked to the potential catching capacity of the vessels to be licensed under the agreement. The payment of the operational fee exempted Japanese fishermen from payment of PNG's statutory 5 percent export tax.

[14]Information supplied by the management of Star-Kist (PNG) Pty. Ltd, and New Britain Fishing Industries Pty. Ltd, Rabaul, 1982.

In determining the $1.45 million access fee payment for Japanese vessels, the PNG Government's policy was that domestic fishermen should not be required to pay a higher rate of tax on their fish than foreign fishermen. Thus the $1.45 million was estimated to be 5 percent ad valorem of the fish landed by the Japanese vessels over the 9-month period of the agreement.

As part of the agreement, the Japanese Government agreed to remove export restrictions on any fishing vessel the PNG Government wished to purchase from Japan. However, this option was never exercised. The agreement also provided for access to Japanese concessional loan finance and technical assistance, specifically for site surveys for tuna bases in Manus and East New Britain (Fig. 1), and design work for a new pole-and-line vessel for the domestic fishery.

A protracted series of negotiations to extend the 1978 Interim Agreement broke down when the PNG Government insisted on a $1.16 million lump-sum payment for a 1-year extension of the agreement. The Japanese fishing industry, facing a serious recession, was convinced that it had paid dearly for access under the 1978 agreement. It therefore found PNG's financial demands for the extension of the agreement unacceptable. To try to prevent an impasse, the Japanese Government offered aid as part of an access fee payment, but this was rejected by PNG on the basis that such aid should be obtained independently of a fisheries agreement and that such agreements should be negotiated on strictly commercial terms.

With the termination of the 1978 Interim Agreement, no Japanese vessels operated legally within PNG's DFZ from February to June 1979. However, following consultations with four Japanese tuna fishing associations, the PNG Government reached an understanding with them and agreed to license individual vessels on a per-trip basis. In most cases, licenses were based on the estimated catch by vessel class sizes and the anticipated Yaizu market value of fish caught. This understanding between the PNG Government and the Japanese fishing associations extended from July 1979 to December 1980, with 357 Japanese vessels fishing within PNG's DFZ.

Although this understanding worked satisfactorily, Japanese industry requested its review and the establishment of a formal agreement based on similar terms and conditions. Discussions began in Japan in 1980 and an agreement was signed in PNG in August 1981. Fee payments under this agreement were premised on an operational fee of 5 percent of the FOB value of the catch valued at average Yaizu prices, a boat license fee of $43.50/m of vessel per year and an annual fisherman fee of $1.45 for each crew member.

Purse-seine, longline, and pole-and-line vessels were granted 2-month trip licenses, while group seiners could obtain 2- or 4-month licenses. The fishing operations of these vessels are described below. The arrangement was negotiated for 1 year (until August 1982) but would remain in force beyond that time until either the PNG Government or the Japanese associations gave a 3-month notice of termination.

During 1981 PNG collected $1,222,722 for 377 licenses issued between January and August and a further $1,181,272 for 240 licenses after the introduction of the arrangement. This resulted in a total payment of $2.4 million for 1981, a total that the Japanese industry would never have agreed to under a lump-sum payment system. In 1982 the Japanese arrangement yielded PNG $3.4 million.

In August 1982, representatives from the Governments of PNG and Japan and the Japanese fishing associations met to review the operation of the arrangement. Parties to the arrangement acknowledged that it was operating satisfactorily and it was mutually agreed that it continue.

In 1980 the Government of PNG initiated discussions with the Government of the Republic of Korea on the possible implementation of a fisheries agreement between the two Governments. It is anticipated that this agreement will be concluded before the end of 1983 and will permit Korean longline and purse-seine vessels to operate within PNG's DFZ under similar terms and conditions to the current Japanese agreement[15].

An Interim Agreement was also reached in April 1982 with the American Tunaboat Association (ATA) to permit American seiners to fish PNG's DFZ until the end of 1982. This agreement resulted from seizure of the U.S. seiner *Danica*. The captain of the vessel was tried and convicted under PNG law for unlicensed fishing within PNG's DFZ. The mandatory penalty for such an offense is confiscation of the vessel and catch. However, to avoid an embargo on PNG exports of tuna and other seafood products to the United States as provided for under the Magnuson Act, PNG was required to release the *Danica* on nondiscriminatory terms and to accept an Interim Agreement under terms basically determined by the ATA. The conditions of this agreement required PNG to license U.S. seiners at considerably lower rates than those charged Japanese seiners. The ATA agreement yielded PNG $454,000 during 1982 but was not renewed in 1983[16].

Although the PNG-ATA agreement favored U.S. vessels in financial terms, it should be noted the ATA concluded an agreement with a single state. This represents de facto recognition by ATA of PNG's fisheries laws and jurisdiction over its tuna stocks.

Purse-Seine Fishery

Most vessels operating in the purse-seine fishery in PNG prior to 1982 were Japanese, although unlicensed vessels from Korea, Philippines, Indonesia, U.S.S.R., Taiwan, and the United States were suspected to have fished within PNG waters. In 1982, Japanese and U.S. vessels operated under agreement within this area. A small number of seiners from other countries also operated under special arrangements.

Japanese and American single seiners operating in the western Pacific are of

[15]Some Korean and Taiwanese purse seiners are already licensed under terms and conditions of the Japanese Agreement.

[16]U.S. seiners were licensed at the rate of $35/NRT of vessel for the period of the agreement. This meant that most seiners paid between $18,000 and $22,000 for the 9-month period for their license.

similar design with a forward superstructure, aft seining, and equivalent sized nets (1,700-2,400 m long, 240 m deep, and 120 mm mesh) (Wankowski, 1980). The U.S. seiners, commonly known as "superseiners," are generally 1,000-1,700 GRT and frequently use helicopters to locate schools of fish. They have a crew of 22, including the aircraft pilot. Japanese single seiners are usually in the 500-750 GRT range with a crew of between 18 and 24 men. Japanese vessels make 5-7 trips to PNG waters each year where they tend to operate as a fleet in the northwest sector of the DFZ.

When U.S. seiners first entered the western Pacific in the late 1970's, catches were not encouraging due to major differences in fishing conditions in the eastern Pacific. In particular, the western Pacific has a deeper thermocline, so fishing techniques had to be adjusted. In 1982, 22 U.S. vessels were licensed to fish in PNG's DFZ. The expected annual catch of each of these vessels in the western Pacific is about 6,000 t/year as opposed to 3,000 t in the eastern Pacific. Many U.S. seiners are now basing their operations in New Zealand, American Samoa, and Guam to maximize catch in the region and minimize costs.

In 1980, group purse-seiners, which usually fish Japan's near-water tuna fishery, extended their operations as far south as PNG. Group seine operations usually involve three vessels, a seiner of about 116 GRT, one or two carrier vessels of 325 GRT, and an anchor vessel of 45 GRT. The vessels are crewed by 23, 15, and 7 workers, respectively. During fishing operations, the anchor vessel attaches itself to the seiner and keeps the seiner from drifting onto the net while it is being pursed. The anchor vessel also prevents the carrier vessel and seiner from drifting together while transferring the catch from the net. The anticipated catch/fishing day for these vessels operating in the western Pacific is 17 t[17].

Table 9. — Species composition of nominal reported catch of single purse-seine vessels operating in PNG's DFZ, 1980-81[1].

	Skipjack tuna			Yellowfin tuna			Bigeye tuna			
Year	t	Percent occurrence	Percent dominance	t	Percent occurrence	Percent dominance	t	Percent occurrence	Percent dominance	Total (t)
1980	10,367	95.7	81.0	2,459	79.7	12.0	80	5.9	0	12,906
1981	10,393	93.8	70.0	4,431	90.8	22.0	114	7.2	0	14,938
Mean	10,380	94.8	75.5	3,445	85.3	17.0	97	6.6	0	13,922

[1] 1979 data not available.
Source: Fisheries Division, PNG Department of Primary Industry, Port Moresby.

Table 10. — Summary of single purse-seine reported operational data from PNG's DFZ, 1979-81.

Total	Licenses issued	No. of vessels	Total sets	Successful sets as % of total	Catch per set (t)	Total catch (t)	Est. value of catch[1] ($10⁶)
1979[2]	n.a.	11	n.a.	n.a.	n.a.	1,555	n.a.
1980	63	12	555	89	23.3	12,906	17.5
1981	103	23	664	92	22.5	14,938	18.0
Mean 1980-81	83	18	610	91	22.9	13,922	17.8

[1] Estimates based on mean annual Yaizu price.
[2] Data available from July only.
Source: Fisheries Division, PNG Department of Primary Industry, Port Moresby.

This is based on the operations of five group seiners in Micronesian waters that landed 12,000 t of fish between February and May 1981, the period that these vessels operate in equatorial waters. Three group seiners were licensed to fish in PNG's DFZ in 1981 but no catch/effort data is available for their operations.

Purse-seining in the western Pacific usually takes place on schools of tuna associated with logs or other floating debris, whales, and sharks. During 1981, 85 percent of schools fished by Japanese single seiners operating within PNG waters, and 68 percent of those fished by group seiners, were log-associated schools. Free-moving tuna schools can yield exceptional catches, but sets on these schools are not always successful as the fish often escape through the bottom of the net before it is pursed. Of 961 sets analyzed for 1980 and 1981 purse-seine operations in PNG's DFZ, 68 percent began between 0400 and 0600 hours.

Target species for the tropical purse-seine fishery are skipjack and yellowfin tuna, which together composed 99.3 percent and 99.2 percent of the catch of Japanese seiners operating within PNG's waters during 1980 and 1981 (Table 9). Fishing operations in 1979 were limited due to delays in finalizing an access agreement. However, during 1980 and 1981 there were successive record catches reported of 12,906 t and 14,938 t, respectively, by the Japanese purse-seine fleet within PNG waters. Twelve vessels were granted 63 trip licenses during 1980 to fish within PNG's DFZ, while 23 vessels purchased 103 licenses in 1981 (Table 10). The average catch per set increased from 17.0 t in both 1977 and 1978 (Wankowski, 1980), to 23.3 t in 1980 and 22.5 t in 1981 (Table 10). This reflects, among other factors, an improvement in techniques with increased familiarity of the fishery.

The estimated market value of the purse-seine catch was $17.5 million in 1980 and $18.0 million in 1981 (Table 10). These figures are based on average Yaizu prices for skipjack of $1.35/kg and $1.29/kg during 1980 and 1981, respectively. The financial yield to PNG from the sale of purse-seine licenses was $365,104 in 1980 and $856,668 in 1981 (Table 11).

Longline Fishery

Apart from about 50 vessels based in the Solomon Islands, Fiji, New Cale-

[17] DPI. 1982. Record of discussion between the Government of Papua New Guinea, the Government of Japan, and the Japanese Fishing Associations. Fish. Div., PNG Dep. Primary Industry, Port Moresby, (mimeo), 32 p.

Table 11. — PNG Government receipts and estimated value of catch for the tuna fishery, 1980-81 (Sources: Tables 6, 8, 10, 14, and 16).

Fishery	Receipts and estimated values (10^6) 1980	1981
Domestic		
Receipts	1.8	1.2
Value of fish	37.3	24.9
Receipts as percent of value of fish	4.9	5.0
Foreign		
Purse-seine		
Receipts	0.4	0.9
Value of fish	17.5	18.0
Receipts as percent of value of fish	2.3	5.0
Longline		
Receipts	0.7	1.2
Value of fish	31.0	35.0
Receipts as percent of value of fish	2.3	3.4
Pole-and-line		
Receipts	0.05	0.01
Value of fish	0.1	0.02
Receipts as percent of value of fish	50.0	50.0
Summary		
Total receipts	3.1	3.4
Total value of fish	85.9	77.9
Receipts as percent of value of fish	3.6	4.4
Domestic receipts as percent of total receipts	61.3	38.2

Table 12. — Reported fishing effort by longline vessels licensed to operate in PNG's DFZ, 1979-81.

Year	Vessels licensed	Licenses issued	Total boat days	Thousands of hooks set
1979[1]	180	n.a.	1,110	1,863
1980	123	312	11,090	17,278
1981[2]	151	507	12,675	19,947
Mean 1980-81	137	410	11,883	18,613

[1]Data available from July only.
[2]Estimated from data reported by Japanese industry and catch returns analyzed at time of writing which accounted for 48 percent of total reported catch.
Source: Fisheries Division, Department of Primary Industry, Port Moresby.

Table 13. — Reported species composition of longline catch landed in PNG's DFZ, 1979-81.

Species	1979[1] t	1979[1] Percent	1980[2] t	1980[2] Percent	1981[3] t	1981[3] Percent
Yellowfin tuna	1,375	82.5	11,484	78.9	13,076	74.3
Albacore	2	0.1	323	2.2	1,268	7.2
Bigeye tuna	211	12.7	1,973	13.6	2,050	11.6
Swordfish	10	0.6	93	0.6	123	0.7
Blue marlin	41	2.5	404	2.8	482	2.7
Striped marlin	1	0.1	7	0.0	10	0.1
Black marlin	14	0.8	101	0.7	163	0.9
Sailfish	8	0.5	85	0.6	195	1.1
Other[4]	4	0.2	87	0.6	246	1.4
Total	1,666	100.0	14,557	100.0	17,613	100.0

[1]Data available from July only.
[2]Data based on analysis of 90 percent of the total catch reported by Japanese industry.
[3]Composition estimated from data reported by Japanese industry and catch returns analyzed at time of writing which accounted for 48 percent of total reported catch.
[4]Includes sharks and other less valuable species.
Source: Fisheries Division, Department of Primary Industry, Port Moresby.

donia, and American Samoa, the western Pacific longline fleet operates from ports in Japan, Korea, and Taiwan. In total there are 2,700 longliners in the Japanese fleet of which an estimated 700 are licensed by the Japanese Government to fish in the western Pacific region. Based on average catch figures for 1976-80, these longliners are estimated to have caught 40,000 t of tuna and billfish annually from the combined fisheries zones of countries in the region.

Distant-water longline operations have been analyzed in detail for the Atlantic and Pacific Oceans (Beare et al., 1963; Kume, 1974; Honma, 1975; Klawe, 1978; Wright, 1980). Most vessels operating within PNG waters are 59 GRT class vessels and have a crew of 10. They average between 4 and 7 fishing trips to PNG each year with each trip being of about 50 days duration. Only about half of each trip is spent actually fishing, the remainder being devoted to traveling to and from the fishing grounds. In a typical fishing day, each vessel sets 2,000 hooks for target yellowfin tuna and bigeye tuna, *Thunnus obesus*, as well as billfish. Wright (1980) estimated that 22 percent of all whole tunas hauled in PNG are discarded because they are too small for the sashimi market and an additional 10 percent are discarded because they are shark-mauled.

During 1980, 123 longliners were issued 312 trip licenses for operation in PNG waters. In 1981, the number of vessels increased to 151 and the number of licenses to 507 (Table 12). In 1980, longliners landed 14,557 t of fish while in 1981 the catch increased by 21 percent to 17,613 t (Table 13). Yellowfin tuna formed 78.9 percent of total catch in 1980 and 74.2 percent in 1981, while bigeye tuna accounted for 13.6 and 11.6 percent, respectively (Table 13).

The estimated market value of the longline catch from PNG waters during 1980 and 1981 was $31 million and $35 million, respectively (Table 14). The financial benefit to PNG from the sale of licenses for this fishery totaled $726,663 in 1980 and $1,185,002 during 1981 (Table 11).

Table 14. — Estimated market value of reported longline catch landed in PNG's DFZ, 1980-81[1].

Species	Market value (10^6) 1980	1981
Yellowfin tuna	23.3	25.3
Albacore	0.6	0.3
Bigeye tuna	6.3	7.6
Other	0.8	1.8
Total	31.0	35.0

[1]Estimates based on reported catch and mean annual Yaizu prices for each species.
Source: Fisheries Division, PNG Department of Primary Industry, Port Moresby.

Pole-and-Line-Fishery

In 1973 Japan had almost 500 distant-water pole-and-line vessels of less than 500 GRT operating in the western Pacific (Ishida, 1975). In 1979 the size of the fleet had dropped to 300 vessels and by 1981 only 120 vessels remained[18]. Part of the reason for this was the Japanese policy, begun in the late 1970's but discontinued in 1982, of reducing distant-water pole-and-line fishing effort by 20 percent. This was achieved through a Government-supervised license buy-back scheme. The maximum number of pole-and-line licenses was fixed by the Japanese Government, and fishermen wanting to re-

[18]DPI. 1982. Papua New Guinea's tuna fishery. Fish. Div., PNG Dep. Primary Industry, Port Moresby, (mimeo), 16 p.

Table 15. — Species composition of nominal reported catch by pole-and-line vessels in PNG's DFZ, 1979-81[1].

	Catch					
	1979		1980		1981	
Species	t	%	t	%	t	%
Skipjack tuna	479	95.2	94	94.9	15	93.8
Yellowfin tuna	15	3.0	3	3.0	1	6.2
Other	9	1.8	2	2.1	0	0
Total	503	100.0	99	100.0	16	100.0

[1]Composition of catch extrapolated from mean composition between 1973 and 1977 as reported by Wankowski (1980).
Source: Fisheries Division, PNG Department of Primary Industry, Port Moresby.

Table 16. — Reported fishing effort by pole-and-line vessels licensed to operate in PNG's DFZ, 1979-81.

	Fishing effort		
Item	1979	1980	1981
Total vessels	24	7	5
Catch (t)	503	99	16
Estimated catch value ($)[1]	n.a.	134,177	20,698

[1]Estimates based on mean annual Yaizu prices.
Source: Fisheries Division, PNG Department of Primary Industry, Port Moresby.

Table 17. — Summary of catch by fishery and species in 1980-81. (Sources: Tables 1, 9, 13, and 15.)

	Catch (t)	
Fishery	1980	1981
Domestic		
Skipjack tuna	30,962	20,521
Yellowfin tuna	3,035	3,508
Other	102	0
Subtotal	34,099	24,029
Foreign		
Purse-seine		
Skipjack tuna	10,367	10,393
Yellowfin tuna	2,459	4,431
Other	80	114
Subtotal	12,906	14,938
Longline		
Skipjack tuna	0	0
Yellowfin tuna	11,484	13,076
Other	3,073	4,537
Subtotal	14,557	17,613
Pole-and-line		
Skipjack tuna	94	15
Yellowfin tuna	3	1
Other	2	0
Subtotal	99	16
Subtotals		
Skipjack tuna	41,423	30,929
Yellowfin tuna	16,981	21,016
Other	3,257	4,651
Grand total	61,661	56,596

main in the fishery collectively compensated those who wished to leave it. Licenses purchased in this way were not reissued so that there was a permanent reduction in the number of fishing vessels licensed to operate in the fishery.

The Japanese Government also instituted a replacement program in the distant-water pole-and-line fishery whereby five licensed pole-and-line boats could be replaced by one seiner, thus reducing the absolute number of vessels without any appreciable loss of fishing capacity. The trend toward replacement of pole-and-line vessels with purse-seiners was encouraged principally because seiners are more efficient and less costly to operate per unit of output.

The literature contains descriptions of the functional aspects of pole-and-line tuna fishing (Tomiyama, 1975) and the geographical expansion of this fishery (Bour and Galenon, 1979). Fewer pole-and-line vessels have fished PNG waters in recent years because there is reportedly less bait mortality and similar fishing grounds closer to Japan around the Marshall Islands and Kiribati. Consequently, fishing effort by Japanese pole-and-line vessels in PNG's DFZ has dropped dramatically in recent years[19].

Most distant-water fishing by Japanese pole-and-line vessels occurs between October and March each year because a near-water fishery exists during the northern summer months. A typical 35 GRT pole-and-line vessel that fishes PNG waters has a crew of between 18 and 24 men and carries about 1.5 t of live bait (Wankowski, 1980).

From 1972 to 1978, pole-and-line vessels operating in the western Pacific took an average of 5.1 t of tuna per fishing day (Wankowski, 1980). Data from catch returns for PNG are not available for 1979, 1980, and 1981, but based on information supplied by Japanese industry, skipjack tuna averaged 93.8 percent and yellowfin tuna 6.3 percent of the pole-and-line catch taken in PNG's DFZ in these years (Table 15). During 1979, 24 vessels caught 503 t of tuna, while in 1980, seven vessels purchased 14 trip licenses for a total catch of 99 t. In 1981, effort was further reduced when only five vessels entered PNG waters on seven trip licenses for a total catch of 16 t (Table 16).

Most tuna caught by distant-water pole-and-line vessels is canned. Based on average Yaizu prices for 1980 and 1981, the annual market value of the PNG catch is estimated to be $134,117 and $20,698, respectively.

The financial benefit to PNG from the sale of licenses in the pole-and-line fishery was $50,586 in 1980 and $15,668 in 1981 (Table 11). These figures highlight the practice of Japanese fishermen purchasing PNG licenses as insurance against the possibility of apprehension for illegal fishing should they stray into PNG's DFZ from adjoining zones in pursuit of moving concentrations of fish.

Fisheries Data Consolidation

Table 17 shows a consolidation of catch data for the domestic and distant-water fisheries for 1980 and 1981. In total, 61,661 t of tuna were reportedly harvested in PNG's DFZ in 1980 and 56,596 t in 1981, and the difference was due almost entirely to a lower domestic catch in 1981. The domestic fishery accounted for 55 percent and 42 percent, respectively, of total tuna landings in 1980 and 1981.

As a proportion of total landings, skipjack tuna was the dominant species harvested, representing 67 percent of the total in 1980 and 55 percent in 1981. On the basis of an estimated annual skipjack tuna maximum sustainable yield (MSY) of 180,000 t for PNG's DFZ, reported skipjack tuna landings in 1980 and 1981 accounted for 23 percent and 17 percent, respectively, of this estimated yield. These results indicate that, provided purse-seine and pole-and-line fishing effort can be spatially distributed optimally within the DFZ, it should be possible to at least double effort over 1980 and 1981 levels without jeopardizing the resource.

Landings of yellowfin tuna as a proportion of total landings were relatively more important in 1981 than in 1980 (37 percent vs. 28 percent), principally because of higher purse-seine and longline

[19]In 1974, 289 Japanese pole-and-line vessels took 57,000 t of tuna in PNG's DFZ (Wankowski, 1980).

catches of this species in 1981.

Government revenue and the estimated value of total tuna landings from PNG's DFZ for 1980 and 1981 are consolidated in Table 11. Total Government receipts from the domestic and distant-water fisheries were $3.1 million in 1980 and $3.4 million in 1981. The drop in receipts in the domestic fishery in 1981 was more than compensated for by increase in revenue from the purse-seine and longline fisheries.

Total Government receipts as a proportion of the estimated value of fish landed in PNG waters was 3.6 percent in 1980 and 4.4 percent in 1981. In both the domestic and distant-water fisheries, the Government aims to appropriate 5 percent of the value of the catch through the imposition of export tax and license fees. In the domestic fishery this goal was achieved in 1980 and 1981. However, ignoring the distant-water pole-and-line fishery because its results are atypical, the 5 percent objective was achieved only in the purse-seine fishery in 1981. In the longline fishery, Government receipts as a proportion of the value of the catch were significantly less than the 5 percent target in both 1980 and 1981. Analysis of Japanese tuna landings and prices undertaken by the Forum Fisheries Agency (FFA) in 1982 implies that PNG's longline catch since 1980 has been undervalued each year by approximately 40 percent[20]. Consequently, if the value of PNG's longline catch is revised upward to reflect its real market value, Government revenue as a percentage of the revised valuation falls markedly. A similar problem does not arise in evaluating the purse-seine catch.

In terms of the accuracy and completeness of PNG's 1980 and 1981 catch data, a word of caution is necessary. While data for the domestic fishery are accurate and reliable because of the established reporting system, the same degree of confidence cannot be placed in data for the distant-water fishery. Consequently, data presented in Table 17 represent minimum catch aggregates only.

The reliability of PNG's distant-water fishery data is affected by three types of underreporting:

1) Failure of licensed vessels to file catch returns. Some vessels licensed to operate in the DFZ fail to complete and file catch returns as required under the terms and conditions of their license. This particularly applies to non-Japanese vessels that operate within PNG waters on an irregular basis. Vessel operators violating this requirement are not usually granted subsequent licenses. Data presented in this paper cover only about 90 percent of trip licenses issued each year.

2) Underreporting of catch by licensed vessels. Because the PNG formulae for determining license fees are linked to catch rates on a historical basis, there is a strong incentive for fishermen to underreport catch/effort data as a means of trying to ensure that fee levels are not adjusted upwards in subsequent access negotiations. It is believed that underreporting is common among purse-seine operators fishing within PNG's DFZ. According to an independent Japanese source, purse-seine catch rates and the time actually spent fishing in PNG waters are higher than is being officially reported.

3) Unlicensed fishing. It is known that unlicensed vessels operate in the DFZ, though the incidence of this type of operation has probably declined following the apprehension of several vessels by PNG naval boats on routine patrols. However, with such an extensive DFZ (approximately 3,120,000 km^2) it is expected that illegal fishing operations will continue but probably not on a regular basis by particular vessels. Given the lack of information on the operations of unlicensed vessels within PNG waters, no reliable estimate of landings by these vessels is currently available.

These types of underreporting show the need for PNG to negotiate future access agreements with DWFN's on a government-to-government basis rather than with industry. With government-to-government agreements, diplomatic pressure can be exerted to ensure that terms and conditions of access are fulfilled. This same degree of influence cannot be so readily exercised by the PNG Government over industry in DWFN's. Regionally, the initiation of the Regional Vessel Register by the FFA and the tracking of voyages for individual vessels within the western Pacific region should make it more difficult for vessel operators to underreport catch/effort data or to fish illegally.

Management

Recognizing the highly migratory nature of tuna and the implications this has for effective resource management, PNG acknowledges that management of tuna stocks in the western Pacific must necessarily be undertaken on a regional basis. It is primarily for this reason that PNG staunchly supported the establishment of the FFA in 1979. More recently, PNG was the prime mover behind the formation of the Nauru Group, seven states in the western Pacific that have shared tuna fisheries and contiguous fisheries zones. This is a subgroup of the FFA[21]. Through consultation and in close cooperation with each other, parties to the Nauru Agreement aim to harmonize and coordinate fisheries policies. This is particularly the case in relation to resource management and terms and conditions of access to the tuna resources of the region by DWFN's.

Quite apart from the legal aspects of the Convention on the Law of the Sea (United Nations, 1980) relating to the management of highly migratory species of fish, the economic and political reasons underlying regional cooperation among the small island states in the western Pacific are compelling. The case for such a management approach has been stated by Kearney (1976), Lawson (1979), and Doulman (1981). From an economic point of view these writers argue that regional management fosters efficiency in resource utilization and that effective regional planning should prevent problems of overcapitalization in the fishery.

Standardized region-wide data collection and centralized analysis by SPC and

[20]FFA. 1982. Skipjack tuna price data for 1982. Paper prepared for the Workshop on Access Negotiations, Vanuatu (23 September-1 October 1982), (mimeo), Econ. Unit, Forum Fish. Agency, 27 p.

[21]The member states are Palau, Federated States of Micronesia, Marshall Islands, PNG, Solomon Islands, Nauru, and Kiribati.

FFA provide basic biological and socioeconomic information necessary for informed management decisions. The costs of regional surveillance and enforcement of fishing agreements should also be lower. This is an important consideration, as costs of this nature can easily whittle away financial gains received from the exploitation of tuna stocks.

In the absence of effective regional cooperation, countries reliant on DWFN's for the exploitation of their tuna stocks will be forced into competition with each other for resource development, thus dissipating part of their resource rent and fostering irrational resource use. The small size of most of the island states in the western Pacific, and their present dependence on DWFN's for harvesting tuna stocks, makes them vulnerable to economic exploitation by DWFN's and their experienced multinational agents. These issues have recently been analyzed by King and Galloway[22].

Future Outlook

Immediate prospects for the domestic fishery are uncertain. While the potential exists for a robust pole-and-line and purse-seine fishery, it appears unlikely that the past pattern of corporate exploitation will be maintained. Future operations will probably directly involve the Government of PNG, Okinawan fishermen, and possibly a European and/or U.S. partner in joint venture arrangements. It is envisaged that part of the domestic catch would be processed within PNG for export (loined and/or canned) and part sold under marketing agreements at world market prices.

An anticipated development in the domestic fishery, if it recommences, will be diversification of fishing operations away from a fleet consisting solely of pole-and-line boats to one composed of both pole-and-line and small (500 GRT class) purse-seine vessels. While significant socioeconomic benefits result from the operation of pole-and-line boats, particularly through employment of PNG nationals, unit production costs by these boats are considerably higher than for purse-seine caught fish. It is estimated that production costs for tuna landed by purse-seiners in PNG are about $150/t less than for fish caught by pole-and-line boats. Consequently, to contain costs and maintain a competitive position, fishing costs in the domestic fishery must be reduced where possible or at least kept at current levels. However, determining the required mix of vessels in the fleet will necessarily involve a trade-off between socioeconomic considerations and those of a strictly financial nature. These decisions must also be made within the guidelines of existing Government policy on industrial development which clearly states that subsidies of any type will not be given to commercial undertakings.

As for the distant-water fishery, it is expected that the rapid build-up in purse-seine activity within PNG's DFZ since 1980 will be maintained, though a lower rate of expansion is anticipated over the next few years. Almost the entire increase in capacity will come from U.S. seiners, though it is expected that additional purse-seine vessels from Korea, Taiwan, and especially the Philippines will enter the western Pacific tuna fishery. The build up in purse-seine fishing effort in PNG's DFZ by U.S. vessels will probably be tempered in some degree by the recent discovery of rich fishing grounds around Kiribati. Operations in this area are preferred by American fishermen because of its proximity to transshipment and processing facilities in American Samoa. However, because of the high catch rates in the western Pacific compared with those in the eastern Pacific, interest by U.S. seiner operators in the western Pacific will certainly remain keen.

The distant-water longline fishery operating within PNG's DFZ is anticipated to continue at current levels of operation over the medium term. A build-up in activity can be expected if fishing areas are closed off to part of the Japanese fleet, as was the case in September 1982 when access negotiations were suspended between the Japanese fishing associations and the Solomon Islands Government. Many of the vessels that had been previously licensed in the Solomon Islands immediately applied for licenses to fish in PNG waters.

A similar situation resulted in early 1982 when the Japanese fishing associations and the Federated States of Micronesia failed to reach agreement on the level of access fee payments. When situations of this type arise, there is a movement of vessels into zones where agreements exist between Japanese industry and coastal states. In the longer term, the number of longline vessels operating in the western Pacific will probably decline because of the effects of rising production costs and flagging demand in Japan.

Recent trends in the distant-water pole-and-line fishery should continue, and in fact it is expected to disappear completely from PNG's DFZ.

In the intermediate term, PNG will attempt to develop shore bases for the transshipment of purse-seine and longline caught fish. Transshipment of longline fish should enhance the profitability of individual operators because expensive and unproductive travel time to and from Japan would be eliminated. However, it appears that the Japanese Government does not favor the development of such overseas bases because the present mode of operation serves to regulate the supply of fish to the Japanese market and thereby support prices[23]. However, provided that restrictions are not placed on transshipment of longline caught fish either by the Japanese Government or industry, the existence of shore bases in PNG capable of handling fish for the sashimi market should encourage fishermen to offload at least part of their catch within the country. The PNG Government could enforce Article 62(4e) of the Convention on the Law of the Sea (United Nations, 1980), which requires fishermen to offload part or all of their catch taken in PNG waters at that nation's ports. But the enforce-

[22]King, D. M., and F. J. Galloway. 1981. A game-theoretic bargaining model of tuna fishing in the South Pacific: Island nations vs. multinational corporations. Paper presented at Western Economic Association Annual Meeting, San Francisco, 24 p.

[23]DPI. 1982. Record of discussion between the Government of Papua New Guinea, the Government of Japan, and the Japanese Fishing Associations. Fish. Div., PNG Dep. Primary Industry, Port Moresby, (mimeo), 32 p.

ment of this provision should not be necessary if it is economically advantageous for fishermen to transship their catch in PNG. It is estimated that longline vessels currently fishing in PNG could increase their fishing time 30 percent by transshipping their catch in the country.

Without the establishment of shore facilities (transshipment and processing), PNG will not be in a position to achieve maximum benefit from the exploitation of its tuna resources. It is recognized that direct financial, employment, and other benefits in the fishing industry are substantial, although these are outweighed by the magnitude of indirect benefits of a similar nature in linked industries. Until strong backward and forward linkages are forged, the full potential of the industry's contribution to the economic development of PNG will not be realized. Thus, the Government intends to press for the establishment of shore-based processing and transshipment facilities as a matter of priority.

At the regional level, cooperation among parties to the Nauru Agreement should improve. Steps are being taken to harmonize fisheries policies between these countries so regional licensing on common terms and conditions for all DWFN vessels can be introduced. This method of licensing will initially be introduced for purse-seiners because of the small number of vessels involved, and will be progressively extended to pole-and-line and longline vessels. Apart from the inherent financial and management advantages for the coastal states in the region from such an arrangement, DWFN vessels will also benefit from having access to a rich resource over a wide area. It will also be administratively simpler for these vessels to operate within the region as many of the restrictions currently in force, through individual states having their own licensing arrangements, will be minimized or removed completely.

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SWFC Research Activities on Albacore and Tropical Tuna, 1981-82

The La Jolla Laboratory of the NMFS Southwest Fisheries Center, La Jolla, Calif., conducts research on Atlantic albacore and tropical tunas in support of the U.S. commitment to the International Commission for the Conservation of Atlantic Tunas (ICCAT). The Center also administers a tuna port sampling program in Puerto Rico, maintains a comprehensive Atlantic tunas data base, facilitates the exchange of data between U.S. and foreign researchers and coordinates general scientific matters involving ICCAT-related research being done by U.S. scientists.

During 1981-82, research continued on stock assessments and fishery evaluations of Atlantic tropical and albacore tunas. U.S. fisheries were monitored and biological and fishery data collected in cooperation with the U.S. tuna industry and government officials. Atlantic tuna imports were sampled for biological information in Puerto Rico. Data collected through these activities were compiled and submitted to ICCAT, as required of ICCAT members.

A document describing 1981 Puerto Rican import sampling activities was prepared for the 1982 SCRS meeting. The 1981 results indicate that 79 percent, by number, of the yellowfin tuna imports sampled, and 83 percent of the bigeye tuna imports sampled were less than 55 cm fork length. Sampling for species composition in Puerto Rico during 1981 indicated that bigeye tuna comprised approximately 8 percent (by weight) of the mixed yellowfin-bigeye tuna import tonnage sampled.

The production model was used to analyze the Atlantic yellowfin tuna fishery. An approach which considers the appropriateness of the different production curves on the basis of current population theory was used to calculate CPUE vectors. Results indicate that maximum sustainable average yield (MSAY) is between 110,000 t and 150,000 t for the Eastern Atlantic, and that the present fishery is operating near this level with the optimal amount of effort.

Between 1975 and 1980, review of Atlantic tropical tuna fisheries focused attention on the expansion of the surface fishery. This expansion consisted mainly of an increase in the number of large purse seiners participating in the fishery and an offshore extension of the fishery in the eastern tropical Atlantic during this period.

Single set data from the U.S. tropical tuna fleet covering the period 1968-81 were analyzed. Changes in fishing patterns and operations were examined with respect to changes in fishing success.

The condition of the South Atlantic albacore stock was evaluated through production model analysis and Monte Carlo Simulation using updated data. The sensitivity of the results to data accuracy was investigated. The production model analysis suggests that the South Atlantic albacore stock is being exploited beyond MSY under the current pattern of fishing.

Research in support of ICCAT's International Skipjack Year Program (ISYP) continues at the SWFC. Maturity-fecundity and feeding behavior of skipjack tuna from the Western Atlantic are being investigated. Gonads and stomach samples were collected from landings in Puerto Rico and Brazil. Gonads are being analyzed historically to determine temporal/spatial distribution of spawning adults, and stomachs are being analyzed for food contents with particular attention to the occurrence and extent of skipjack cannibalism in the Western Atlantic. A new approach to stock identification using mitochondrial DNA is also being investigated.

Fish Attraction Buoys Deployed off California

The use of anchored buoys as "fish aggregating devices" (FAD's) was pioneered in the United States by the Honolulu Laboratory of the Southwest Fisheries Center (SWFC). After initial success in Hawaiian waters, the use of FAD's spread to many of the islands in the central and south Pacific. Perhaps the most successful employment of FAD's is in the tuna purse seine fishery in the Philippines, where for many years, "payaos," rafts constructed of bamboo, have been used to aggregate tunas.

Off the California coast, bluefin tuna show up regularly in summer and fall, and are caught by purse seiners working out of San Pedro and Port Hueneme. Researchers at the SWFC Laboratory at Tiburon, Calif., believe the FAD's deployed at strategic areas may attract and hold the fish, providing greater efficiency to the fishery. A cooperative project to install FAD's has been initiated by the Fishermen's Cooperative Association of San Pedro, the Southwest Region of NMFS, and the SWFC Tiburon Laboratory.

The staff of the Fisheries Development Task at Tiburon assembled equipment and materials needed to build FAD's for deployment in the vicinity of Sixty Mile Bank last summer. Much of the equipment needed for constructing the FAD's was donated by the U.S. Coast Guard. Coast Guard personnel as well as personnel of the SWFC Honolulu Laboratory also contributed useful technical advice on how to construct and anchor the FAD's. Early reports showed evidence of their worth. Reports from sport fishermen indicated that many fish—mostly skipjack tuna—had been taken near both FAD's.

Nineteen Named to Regional Fishery Management Councils

Malcolm Baldrige, Secretary of Commerce, has appointed 19 people to the nation's eight Regional Fishery Management Councils. The appointments (R = Reappointment) are as follows. Caribbean Fishery Management Council: Arthur E. Dammann, R, former chief scientist, Caribbean Fishery Management Council, St. John, V.I. Gulf of Mexico Fishery Management Council: John M. Green, R, President, Mil-Vid Properties, Inc., Beaumont, Tex.; George A. Brumfield, R, Vice President—Operations, Zapata Haynie Corporation, Moss Point, Miss.; Mary A. Kumpe, governing board member, Southwest Florida Water Management District, Brooksville, Fla.

North Pacific Fishery Management Council: John R. Winther, owner, fishing vessel, *Teresa Marie*, Petersburg, Alaska; Sara S. Hemphill, President, Trading Company of Alaska, Anchorage, Alaska. Pacific Fishery Management Council: Richard A. Schwarz, assistant manager/engineering and projects, USDOE, Idaho Operations Office, Idaho Falls, Ida.; Robert G. Kaneen, retired from the California Department of Fish and Game, Long Beach, Calif. (and on 3 August 1983, Roger Thomas was appointed to the Council's California obligatory vacancy). South Atlantic Fishery Management Council: J. M. Pendarvis, R, owner, Pendarvis Chevrolet, Edgefield, S.C.; Margaret A. Stamey, R, member, North Carolina General Assembly, Raleigh, N.C.

Western Pacific Fishery Management Council: Gertrude I. Nishihara, R, founding member and board director of the Hawaii Fishing Coalition, Honolulu, Hawaii; Paul Stevenson, R, program director, Division of Instructional Development, Department of Education, Pago Pago, American Samoa. Mid-Atlantic Fishery Management Council: Alfred J. Hurlock, Jr., R, owner and President, Hurlock Roofing Co., Wilmington, Del.; David H. Hart, R, retired commercial fisherman, Cape May, N.J.; Harry M. Keene, R, owner, Bay County Industrial Supply Co., Easton, Md.; James F. McHugh, R, consultant, Hampton, Vir. New England Fishery Management Council: Herbert R. Drake, owner, Drake's Harborside Fish Market, Rye, N.H.; Alan D. Guimond, President, Stonington Seafood Products, Point Judith, R.I.; William A. Lund, Jr., associate professor, Department of Marine Sciences, University of Connecticut, Noank, Conn.

The Fishery Management Councils, established by the Magnuson Fishery Conservation and Management Act of 1976, prepare management plans for the fishery resources within their geographic area. Council members are selected from nominees submitted by the governors of the states served by each council.

U.S. Sends Dry Salted Cod Sales Mission to Brazil

Six U.S. firms and Mission Director Milton M. Rose, NMFS, returned on September 21, 1983, from a 10-day codfish sales mission to Brazil with stops in Sao Paulo, Salvador da Bahia, and Rio de Janeiro. The mission's goals were to explore the market potential for exports of U.S. cod to Brazil and to position U.S. firms for future market penetration.

Brazil is an important consumer of dry salted species (bacalhau) and in 1982 imported 16,950 tons worth $42 million. Over 90 percent of this fish was imported from Norway. Although at this time Brazil does not import any seafoods from the U.S., it exports annually to this country $120 million worth of shrimp, lobster tails, tuna and other species.

The U.S. Foreign Commercial Service and the U.S. Embassy in Brazil provided extensive support and arranged for publicity and appointments prior to the mission's arrival. The participants received detailed briefings and background material on the Brazilian market and over 170 business meetings were held with Brazilian importers, brokers, agents, bankers, and government officials. In addition, mission members had the opportunity to make contact with importers and key government officials at receptions hosted at each location by U.S. Consuls as well as at lunches and dinners where U.S. cod dishes were served.

The mission received wide exposure in the Brazilian press, radio, and television. Although the participants did not expect to make any sales, some did manage to sell products. In addition, all developed an excellent understanding of the market and concluded solid business relationships which will lead to future sales, barter, and joint ventures. According to the participants, the mission was a tremendous success.

Guatemala, Honduras Sign Tuna Agreement

Guatemala and Honduras have signed a tuna licensing agreement that should allow U.S. vessels access to major tuna grounds in the eastern tropical Pacific during the 1984 fishing season, according to the National Oceanic and Atmospheric Administration (NOAA).

The agreement, signed by the United States, Costa Rica, and Panama on 15 March 1983, goes into effect as soon as five coastal nations have ratified it. The United States Senate gave its approval for ratification on 27 July. U.S. officials expected all five countries to ratify the agreement by the end of the year.

NOAA said the new multinational accord should end the cycle of seizures of U.S. tuna boats because of conflicting jurisdictional claims and the subsequent imposition of retaliatory embargoes required by U.S. law. The agreement will allow fishermen of any nation that is party to the treaty to buy licenses to fish for tuna in a broad area of the Pacific, including the 200-mile fishery conservation zones of the member nations.

Fees charged fishermen from the first five countries to ratify the agreement will be $60 per net-registered-ton. That fee may be renegotiated up to $100 per net-registered-ton as other countries subsequently join the treaty. Modern U.S. tuna boats are typically about 600 net-registered-tons. Tunas covered by the agreement include yellowfin, skipjack, bigeye, albacore, bluefin, bonito, black skipjack, bullet, frigate, and kawakawa.

Ocean Pollution Data and Information Network

NOAA's Ocean Pollution Data and Information Network (OPDIN) has been established to improve dissemination of data and information resulting from ocean pollution programs conducted or sponsored by the U.S. Government. Ocean pollution data and information tend to be collected to serve the programmatic goals of particular agencies and stored in forms useful primarily to project investigators and agency personnel. Furthermore, it is often difficult for both Federal and non-Federal users to determine what ocean pollution data are available from Federal sources and how to obtain them. The OPDIN is being developed as a coordinating mechanism to make these data and information more accessible and useful.

In May 1981, NOAA's National Oceanographic Data Center (NODC) established the Central Coordination and Referral Office (CCRO) to head the development and operation of the Network. The goals of the Network are to: 1) Improve the accessibility and usefulness of Federal ocean pollution data and information to both Federal and non-Federal users, and 2) strengthen Federal interagency communication and coordination regarding ocean pollution data and information, as well as state, regional, and private sector awareness of these resources.

The Network is intended to supplement (rather than replace) existing agency data and information sources and will utilize existing facilities where possible. The essential components of the Ocean Pollution Data and Information Network are now in place and available to provide service to users. The CCRO is able to provide or assist in providing specific ocean pollution information or data and data products from Federal sources, as well as from state agencies, academic institutions, and other non-Federal facilities.

CCRO establishment has enabled OPDIN to begin fulfilling one of its primary functions: Providing users of Federal ocean pollution data and information with a single contact point. In addition, a number of tasks to improve accessibility of ocean pollution data and information have been completed or are underway. Significant accomplishments to date include: 1) Regional Coordination and Referral Offices (RCRO's), 2) Network Design, 3) The National Marine Pollution Information System (NMPIS), 4) NODC Marine Toxic Substances and Pollutants Data System, 5) Coastal Ocean Pollution Assessment News (COPAS), 6) Coastal Information System, 7) Pollution Data Entry Evaluation Project, and 8) OPDIN Round Table.

General information on Network activities and developments is available without charge. Requests for ocean pollution data and information from NOAA or from other Federal agencies are fulfilled at costs determined by the individual agencies. Costs of data and information products generally depend on the size and complexity of requests and on the ability of the activity to provide the needed products.

Requests for NOAA ocean pollution data and information or for assistance in obtaining ocean pollution data and information from other agencies or activities may be directed to Ocean Pollution Data and Information Network/CCRO, National Oceanographic Data Center, NOAA/NESDIS E/OCx8, Washington, DC 20235 (telephone 202-634-7510 or FTS 634-7510).

American Lobster Fishery Management Plan Approved

Conditional approval of the American Lobster Fishery Management Plan was announced late last summer by the NMFS Northeast Regional Office. The Plan was developed by the New England Fishery Management Council to implement the Federal share of a coastwide lobster management program. Regulations to implement the Plan were published in the *Federal Register* on 10 August 1983. The Plan will promote consistent coast-wide management of this valuable fishery. Many of the measures are currently imposed by the coastal states where lobsters are landed. The measures are scheduled to take effect over a period of 3 years. The measures and their effective dates are as follows:

7 September 1983

Landing or possession of lobster meat was prohibited. Lobster parts may be landed (until 1 January 1986), provided that the sixth tail segment measures at least $1^{1}/_{16}$ inches in length and that not more than two claws are landed with each lobster tail. Landing of female lobsters bearing extruded eggs are prohibited, as is the removal of such eggs or the possession of lobsters from which eggs have been removed.

Vessel owners intending to fish for lobster in the fishery conservation zone (from 3 to 200 miles offshore) are required to obtain permits issued by NMFS or through cooperative agreements with the coastal states. NMFS will attempt to establish cooperative agreements with each State before the start of the 1984 fishing season. Until that time, the NMFS Regional Director indicated that as a matter of practicality a valid State lobster fishing license would be sufficient for fishing in the FCZ. After 1 January 1984, State licenses will only be accepted for FCZ fishing if the

license is properly endorsed and issued under a cooperative agreement. After 1 January 1984, fishermen who wish to apply for a lobster permit should contact their State marine fisheries agency to determine whether a cooperative permit program is in effect for their State. Any fisherman may also apply directly to NMFS for an FCZ permit. Information about the lobster fishery will be collected using the NMFS Three Tier Fishery Information Collection System.

1 January 1985

All lobsters landed whole must meet a minimum carapace length of $3^{3}/_{16}$ inches. All traps must be vented to allow release of sublegal lobsters and be marked with the owner's identification.

1 January 1986

All lobsters must be landed whole. A measure prohibiting the possession of V-notched lobsters in the fishery conservation zone in portions of the Gulf of Maine was also conditionally approved, for a period not to exceed 120 days (ending 4 January 1984) from 7 September 1983. The conditional approval made the measure effective on an interim basis while the New England Council considered modifications which would extend the measure throughout the range of the fishery and provide for enforcement at the dock. The public had an opportunity to comment on any changes in the regulations required by these modifications.

During the 120-day conditional approval, it was unlawful for fishermen to retain on board in the V-notch conservation area any lobster bearing a V-shaped notch in the right flipper next to the middle flipper, or any female lobster which is mutilated in a manner which could hide or obliterate such a mark. The V-notch conservation area is that part of the fishery conservation zone north and east of a line which begins at a point lat. 43°06′N, long. 70°34′W, and runs due southeast to a point lat. 42°N, long. 69°35′W, and then runs due east along the 42nd parallel to the seaward limit of the fishery conservation zone.

Fishermen or interested members of the public may obtain a copy of the Federal lobster fishery regulations by writing to the National Marine Fisheries Service, State Fish Pier, Gloucester, Massachusetts 01930. Mark the envelope "Request for Lobster Regulations."

Hawaiian Cruise Nets Squid Data

The National Oceanic and Atmospheric Administration (NOAA) ship, *Townsend Cromwell* returned to Honolulu on 25 September 1983, ending a 53-day fishery research cruise in the central North Pacific to assess squid resources between the Northwestern Hawaiian Islands and the fishing grounds of the North Pacific commercial squid gill-net fishery. Automatic squid jigging machines, surface gill nets, and midwater trawls were used on the cruise, according to Richard S. Shomura, Director, Honolulu Laboratory, SWFC.

Two kinds of squids, flying squid and red squid, both species caught and utilized commercially by the Japanese, comprised the bulk of the catch (92 percent by number and 98.8 percent by weight). Although their distribution overlaps during parts of the year, there was a clear separation of the species during the cruise. Flying squids were taken south of lat. 35°N, whereas red squids were taken north of this latitude. The commercial gill-net fishery for red squid extends from lat. 40° to 50°N in the central North Pacific. Other species of squids taken during the cruise were the striped squid (1-14 at stations between lat. 29° and 40°N, and two juvenile *Onychoteuthis banksii* at lat. 33° and 37°N).

Jigging was the most effective means of catching the squids, according to Walter M. Matsumoto, Chief Scientist on the cruise. The best catch of flying squids (5.0 kg per machine per hour) was made at lat. 30°N, whereas that of red squids was at lat. 42°N (13.4 kg per machine per hour). The latter catch rate is comparable with the catch rate of about 10.0 kg per machine per hour attained by commercial jigging boats in the Japanese squid jig fishery.

Fishing with a limited amount of gill nets 0.55 miles long and composed of nets with mesh sizes ranging from 2.5 to 7.5 inches, 55 red squids were taken in three sets at lat. 41-42°N. Most of the squids (53) were taken on the 2.5- and 3.5-inch mesh nets and two were taken on the 4.5-inch mesh net. None were taken on the 5.5- and 7.5-inch mesh nets.

The midwater trawl caught 166 juvenile postlarval squids representing 6 or more species from lat. 27° to 42°N; 36 percent of the catch was tentatively identified as red squid. The presence of juveniles and postlarvae suggests that the area is a spawning and nursery ground for these species. Matsumoto noted two interesting observations. One squid measuring 49.5 cm and weighing 3.5 kg (7.7 pounds) was taken at lat. 42°N, inside the area of the commercial gill-net fishery; and a second, measuring 52.6 cm and weighing 4.5 kg (9.9 pounds), was taken at lat. 33°N, well south of the fishery. Both squids exceeded the presently known maximum size of 45 cm for this species.

The second was the capture of flying squids in moderate to large numbers in the area to the south of the commercial fishery. Additional cruises to the area and in different seasons should provide the data necessary to determine if the concentration of this species of squid is large enough to support a commercial fishery.

Matsumoto was assisted on the cruise by Research Assistant Victor A. Honda of the Honolulu Laboratory. Other scientists participating in the cruise were Dean Parsons, National Marine Fisheries Service, Washington, D.C. and Hiromichi Yatomi, Tokai University, Japan.

Prepared and Preserved Fish Imports Are Up 22%

The United States International Trade Commission has released a report indicating that during 1978-82, U.S. imports of prepared or preserved fish increased from 234 million pounds to 285 million pounds, or about 22 percent.

The imports consisted primarily of canned fish, much of which is similar to the types of such fish domestically produced. Imports of prepared or preserved fish have supplied about one-quarter of U.S. consumption of such fish in recent years. During the period, U.S. exports, which showed an irregular upward trend from 81 million pounds in 1978 to 102 million pounds in 1982, consisted mainly of fish roe. U.S. consumption, consisting mostly of canned fish, averaged about 1 billion pounds a year and showed no marked shifts.

U.S. production of prepared or preserved fish showed no discernible trend in terms of quantity, reaching a high of 1.0 billion pounds in 1981 and a low of an estimated 0.8 billion pounds in 1982. The U.S. industry consists of hundreds of firms that prepare or preserve fish in canned, cured, and speciality forms; most of the firms are located in coastal areas.

This report is one of a series of summaries of trade and tariff information containing information on U.S. imports, exports, production, and conditions of competition in world trade. The summaries are designed to meet the needs of wide and varied interests, including the Congress, the courts, Government agencies, importers, domestic producers, research organizations, and many others. The summaries contain descriptions of the thousands of products imported into and exported from the United States and information on product uses, U.S. producers, and customs treatment. The summaries also include analyses of the trade, as well as those bearing on the competitiveness of U.S. industries in domestic and foreign markets.

Copies of the report (USITC Publication 841, Control No. 1-3-37) can be obtained from the Office of the Secretary, United States International Trade Commission, 701 E Street NW, Washington, DC 20436.

Puget Sound Squid Resource Evaluated

The Utilization Research Division of the Northwest and Alaska Fisheries Center (NWAFC) has been cooperating with the Washington State Department of Fisheries and a commercial fishing vessel owner in evaluating the commercial potential of squid, *Loligo* spp., taken from Puget Sound.

About 350 pounds of squid, caught by the fishing vessel *Elusive* in Port Angeles harbor, were evaluated for process yields, fresh storage characteristics, and marketability. The squid, harvested by brail, ranged in size from 87.5 to 134 mm (mantle length) and weighed from 28 to 79 g. The sizes observed here generally corresponded with the size of squid typically found in the California fishery as reported by Kato and Hardwick (FAO Fish. Rep. (170) Suppl. 1:150 pp., 1975).

About 19 pounds of squid (average 8.0 count squid/pound) were processed by hand which included removing tentacles, viscera, and skin and washing the mantles. This yielded 6.2 pounds (33 percent) of mantles or steaks and 3 pounds (16 percent) of tentacles for a total recovery of edible meats of 49 percent. A similar yield was obtained for small (13 count) squid. Ten pounds of 9 count squid were skinned by machine (Townsend Model 7000[1]) with little or no difficulty. The Townsend will skin whole or cleaned (mantle tubes only) squid at about 15 squid/minute. With a little practice, the skinning rate can be increased. The yield of cleaned tubes from this operation was 38 percent.

Squid are normally bleached by soaking in fresh water slush ice before they are packed and frozen. This requires about 4-8 hours of soaking with several stirrings. Besides bleaching for marketing, this process also serves to remove much of the "squid ink" while increasing weight. In our preliminary tests, the squid increased their gross weight by 10.7 percent in 4 hours.

Squid packed 40 pounds/bag, iced and stored at 35°F, spoiled in 3½ days after landing. Spoilage was characterized by an intense sulphur dioxide odor and reddening of the white mantle flesh. Squid held in slush ice were of acceptable quality through 4½ days of refrigerated storage.

Several local brokers familiar with squid products were invited to evaluate the quality of our 2.5-day frozen product. The concensus was that the products were of excellent quality and compared favorably with squid products produced in California.

Harold J. Barnett

Reward for Tagged Pollock

During September 1983, fisheries biologists tagged small "harbor" pollock along the central Maine Coast. Each tag is a yellow spaghetti-like tube which is inserted below the dorsal fin, and a $3 reward will be given for each returned tag.

Anyone capturing a tagged pollock should return the tag, together with information on the date and location of capture, to the nearest National Marine Fisheries Service (NMFS) port agent

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

This statement is required by The Act of August 12, 1970, Section 3685, Title 39, U.S. Code, showing ownership, management, and circulation of the *Marine Fisheries Review*, publication number 366-630, and was filed on 29 September 1983. The *Review* is published quarterly (four issues annually) with an annual subscription price of $8.75 (sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402). The complete mailing address of the office of publication is: Scientific Publications Office, F/NWR1, NMFS, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. The complete mailing address of the headquarters of the publishing agency is: National Marine Fisheries Service, NOAA, Department of Commerce, 2001 Wisconsin Ave., N.W., Washington, DC 20235. The name of the publisher is Jack McCormick and the editor and managing editor is Willis Hobart; their mailing address is: NMFS Scientific Publications Office, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. The owner is the U.S. Department of Commerce, 14th St., N.W., Washington, DC 20230; there are no bondholders, mortgagees, or other security holders. The purpose, function, and nonprofit status of the organization (agency) and the exempt status for Federal income tax purposes has not changed during the preceding 12 months. The extent and nature of circulation is as follows: Total number of copies (A) (average number of copies of each issue during the preceding 12 months) was 2550 and the actual number of copies of the single issue published nearest to the filing date was 2551. Paid circulation (B) is handled by the U.S. Government Printing Office, Washington, DC 20402, and (C) the total number printed for their sales (mail subscriptions and individual sales) was 750 for both the average number of copies each issue during the preceding 12 months and the actual number of copies of the single issue published nearest to the filing date. Free distribution (D) by mail, carrier or other means, samples, complimentary, and other free copies (average number of copies each issue during the preceding 12 months) was 1800 and the actual number of copies of the single issue published nearest to the filing date was 1801. The total distribution (E: sum of C and D) (average number of copies each issue during the preceding 12 months) was 2550 and the actual number of copies of the single issue published nearest to the filing date was 2551. There were no copies not distributed or returned from news agents (F). The total (G: sum of E and F) is equal to the net press run figures shown in item A: 2550 and 255 copies, respectively. I certify that the statements made by me above are correct and complete. (Signed) Jack McCormick, Publisher.

(offices in Rockland, Portland, and Gloucester), or to the nearest Maine Department of Marine Resources (MDMR) office or representative.

The tagging project is a cooperative effort between the NMFS Northeast Fisheries Center (NEFC) in Woods Hole, Mass., the MDMR, and the Canadian Department of Fisheries and Oceans in Dartmouth, Nova Scotia. According to Stephen H. Clark, Chief of the NEFC's Gulf of Maine-Georges Bank Resources Investigation, the project "should provide information for distinguishing different pollock populations, or 'stocks,' and for determining migration patterns in the western Gulf of Maine." Clark adds that "such information is needed to effectively manage pollock resources in the Northwest Atlantic."

The Canadian Department of Fisheries and Oceans has tagged small harbor pollock along the east coast of Nova Scotia for several years. Those tagged fish have been recaptured throughout the Scotian Shelf region, and a few have also been recaptured on eastern Georges Bank and in the central Gulf of Maine. Until now, no comparable tagging study has been done for the large concentrations of small harbor pollock found in some areas along the Maine coast in summer and autumn.

NOAA's Environmental Satellite Data Archive

NOAA's Satellite Data Services Division (SDSD) functions as the official U.S. archive for all data and information from NOAA's geostationary and polar-orbiting satellites, i.e., the Metsat system, as well as several NASA experimental satellites and some of the U.S. Defense Meteorological Program satellites.

As a part of the National Environmental Satellite, Data, and Information Services (NESDIS), SDSD is located in the World Weather Building near Washington, D.C. This arrangement gives the Division access to near-real-time data concerning the operational environmental satellites under NOAA's management. It also facilitates the transfer of digital tapes and photographic negatives between the two organizations whenever the need arises.

The Satellite Data Services Division's archive dates back to April 1960, with data from the original TIROS-1 satellite, and continues through the present. Included in the archive today are data from the complete TIROS series, ESSA series, ITOS/NOAA series, and ATS/SMS/GOES series of spacecraft.

Currently, SDSD is receiving digital data and film products from the two operational geostationary satellites—GOES-East and GOES-West—every half-hour, 24 hours a day, in addition to data from the polar-orbiting satellites, NOAA-7 and NOAA-8, plus NASA's NIMBUS-7 with its experimental Coastal Zone Color Scanner. Over 10 million photographic negatives and the equivalent of over 250,000 computer-compatible tapes have been archived to date.

Products available from the Satellite Data Services Division include both full- and reduced-resolution digital data from the NOAA satellites, as well as photographic prints measuring up to 30 by 30 inches. Prices for a digital tape start at $99 each; 10-inch black-and-white photographic prints start at $8.50. Analysis charts (both historical and current) are available on a subscription basis, with weekly mailings.

Several products available through the Division are currently being used by organizations who are also familiar with Landsat data. These products include tapes and film of images acquired by the SEASAT Synthetic Aperture Radar (SAR) sensor, and high-resolution (1.1 km) data from the Advanced Very High Resolution Radiometer (AVHRR) sensors aboard the present NOAA-series polar-orbiting satellites. SAR data, with 24-m resolution, have provided a wealth of information for the geologic and oceanographic community, offering coverage from July-October 1978 over the United States, Canada, Central America, Western Europe, Greenland, Iceland, and the surrounding waters. AVHRR data, with 1-km resolution as compared to Landsat's 80-m resolution, have proven useful as a source of multichannel information which can be acquired twice daily over any specified region of the world.

The staff at SDSD—meterologists, oceanographers, systems analysts, and others—is ready to help users get environmental remote sensing data that fit their needs. Additional information on SDSD products, services, ordering procedures, and prices can be obtained by contacting: NOAA/NESDIS, Satellite Data Services Division, World Weather Building—Room 100, Washington, DC 20233; telephone: (301) 763-8111.

Double Freezing Pollock Is Tested in Alaska Lab

The Kodiak Laboratory of the NWAFC Utilization Research Division has participated in a cooperative experiment with a group of Alaska-based fishermen and a company representing a Chinese firm interested in processing Alaska pollock. The experiment involved freezing whole pollock held for various periods on ice, then thawing the fish, filleting, and refreezing in the fillet block form. This mode of operation has been considered to be one method of handling Alaska pollock for domestic use and is of considerable interest.

The tests at Kodiak consisted of two phases. The first was simply the preparation of blocks to be evaluated by the fishermen's potential customer. The second phase was a laboratory-scale test using pollock held on ice for periods of 3, 4, and 5 days. Samples of each lot were frozen whole and stored at −18°C. After 45 days, the fish were thawed, filleted, packed into 16.5-pound blocks, and refrozen. Following an additional storage period of 30 days, the blocks were evaluated along with fillets prepared from single frozen lots.

The results show detectable quality loss due to double freezing. However, the quality is acceptable and the change is probably not sufficient to justify rejection by a commercial user. If the product is acceptable to the user, the trawlers landing fresh Alaska pollock at Kodiak and Kodiak processors will have a market for whole frozen fish.

Richard W. Nelson

U.S. Tuna Imports From Latin America, 1978-82

United States tuna imports from Latin America increased in 1982 for the first time in 3 years, even though embargoes were in place on tuna and tuna products from some of the region's major tuna fishing countries. Shipments from the region totaled 56,900 metric tons (t) of tuna in 1982, an increase of 50 percent from the 37,900 t imported in 1981, but still well below the record 76,800 t imported in 1979 (Fig. 1, Table 1). The value of tuna imported from Latin America has also increased (Table 2) and set a new all-time record of $67.1 million (before adjustments for inflation).

The overall decline in U.S. tuna imports from Latin America is surprising as several countries (Brazil, Mexico, and Venezuela) have aggressively expanded their fleets and sharply increased their tuna catches. The main reason for the reduced tuna imports has been the imposition by the United States of embargoes on tuna and tuna products from countries which seized U.S. tuna purse seiners for violation of claimed jurisdictions that the United States does not recognize. Embargoes were imposed on Costa Rica, Ecuador, Mexico, and Peru

Table 1. — Latin American tuna exports to the United States, in metric tons 1978-82.

	Exports (t)				
Source	1978	1979	1980	1981	1982
Caribbean					
Bahamas[1]	529.7				
Barbados				68.0	
Bermuda[1]	6,300.7	4,380.6		445.7	405.7
Cayman Isl.			294.8	1,908.9	7,833.5
Cuba					
Dominican Rep.				19.1	
Fr. West Indies		59.2	14.7	56.8	0.6
Grenada					
Haiti					
Jamaica					
Montserrat					
Neth. Antilles	7,670.9	11,753.9	11,837.0	2,334.5	913.5
Trinidad-Tobago		12.5	242.2	522.9	19.7
Total[2]	14,501.3	16,206.2	12,388.7	5,355.9	9,173.1
Central America					
Belize					
Costa Rica	573.2	558.0	450.0		787.6
El Salvador					201.4
Guatemala					
Honduras	4.7				
Mexico	17,853.3	10,038.1	4,730.7		
Nicaragua	2,988.4	846.0			
Panama	14,519.9	25,684.9	16,201.7	14,297.3	21,695.1
Total[2]	35,939.5	37,127.0	21,382.3	14,297.3	22,684.1
South America					
Argentina			23.9	12.2	45.8
Bolivia					
Brazil	708.2	395.0	4,743.6	6,286.4	14,122.1
Chile			3.7	25.4	39.3
Colombia					
Ecuador	12,535.5	17,134.5	11,845.2		1.8
Fr. Guiana					
Guyana					
Paraguay					
Peru	40.6	225.4	745.0	303.8	137.2
Suriname					
Uruguay	2,654.2	710.8	1,602.9	1,639.1	1,058.9
Venezuela	9,324.4	5,066.1	4,062.0	9,970.7	9,615.1
Total[2]	25,262.9	23,531.8	23,026.2	18,237.6	25,020.2
Grand Total[2]	75,703.7	76,865.0	56,797.2	37,890.8	56,877.3

[1]These islands are not physically located in the Caribbean, but are included here for organizational simplicity.
[2]Totals may not agree due to rounding.
Source: Bureau of the Census, U.S. Department of Commerce.

Table 2. — Latin American tuna exports to the United States, by value, 1978-82.

	Exports (US$1,000)				
Source	1978	1979	1980	1981	1982
Caribbean					
Bahamas[1]	$ 175.2				
Barbados				$ 222.2	
Bermuda[1]	1,599.4	$1,337.4		520.6	$ 448.5
Cayman Isl.			$ 277.7	2,279.2	9,197.8
Cuba					
Dominican Rep.	199.7			35.2	
Fr. West Indies		97.4	53.1	124.2	1.1
Grenada					
Haiti					
Jamaica					
Montserrat					
Neth. Antilles	7,823.9	10,072.9	14,395.1	4,576.0	1,177.4
Trinidad-Tobago		21.7	523.1	710.3	35.1
Total[2]	9,798.2	11,529.5	15,249.0	8,467.7	10,860.0
Central America					
Belize					
Costa Rica	499.9	464.4	382.7		826.8
El Salvador					181.0
Guatemala					
Honduras					
Mexico	16,221.7	9,976.6	5,111.0		
Nicaragua	1,598.4	716.0			
Panama	12,605.9	23,410.7	18,799.6	18,270.8	25,832.8
Total[2]	30,925.9	34,567.9	24,293.3	18,270.8	26,840.6
South America					
Argentina			42.6	26.8	92.1
Bolivia					
Brazil	448.3	291.8	5,206.2	7,441.1	15,709.2
Chile			4.4	35.6	65.7
Colombia					
Ecuador	7,941.9	12,186.6	11,136.4		2.3
Fr. Guiana					
Guyana					
Paraguay					
Peru	53.3	306.6	1,083.2	494.6	277.9
Suriname					
Uruguay	4,433.9	985.2	3,383.0	2,749.7	2,264.1
Venezuela	7,858.7	2,711.4	3,068.9	12,793.7	10,940.2
Total[2]	20,736.1	16,481.6	23,925.1	23,541.5	29,351.5
Grand Total[2]	61,460.2	62,579.0	63,467.4	57,061.3	67,052.1

[1]These islands are not physically located in the Caribbean, but are included here for organizational simplicity.
[2]Totals may not agree due to rounding.
Source: Bureau of the Census, U.S. Department of Commerce.

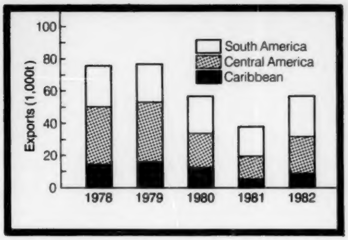

Figure 1. — Latin American tuna exports to the United States, 1978-82.

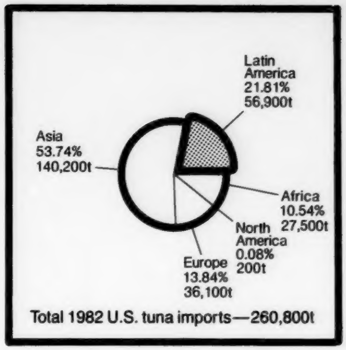

Figure 2. — U.S. tuna imports, 1982.

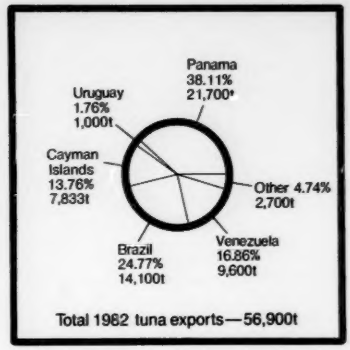

Figure 3. — Latin American tuna exports to the United States, 1982.

Table 3. — U.S. tuna imports by continent, 1978-82.

Continent	Imports (1,000 t) 1978	1979	1980	1981	1982
Asia[1]	205.7	198.4	201.5	205.3	140.2
Lat. America	75.7	76.7	56.8	37.9	56.9
Europe[2]	17.9	11.3	17.7	36.6	36.1
Africa	33.3	27.0	23.2	27.4	27.5
N. America	0.1	0.1	0.1	0.2	0.2
Total[3]	332.7	313.5	299.3	307.4	260.8

[1] Includes Oceania.
[2] Includes eastern and western Europe.
[3] Totals may not agree due to rounding. Totals may also not agree with tuna import data published in "Fisheries of the United States" as Bureau of the Census data does not include shipments from American Samoa.
Source: Bureau of the Census, U.S. Department of Commerce.

Table 4. — Latin America's tuna exports to the United States, 1978-82.

Type of product	Exports (1,000 t) 1978	1979	1980	1981	1982
Fresh/frozen	75.4	76.6	56.0	37.6	56.9
Canned	0.3	0.1	0.5	negl.	negl.
Total	75.7	76.7	56.5	37.6	56.9

Source: Bureau of the Census, U.S. Department of Commerce.

in 1980. The embargo on Costa Rica was removed in February 1982. The embargoes on Ecuador and Peru[1] were removed during April 1983. Two of the countries affected by these embargoes, Ecuador and Mexico, were formerly major suppliers of tuna to United States canneries.

Still, Latin America supplies only a small portion of U.S. tuna imports. The United States imported about 56,900 t from Latin America in 1982, over 20 percent of total U.S. tuna imports (Fig. 2). Most U.S. tuna imports come from Asian countries, primarily Japan, Taiwan, and the Philippines. Imports from Asia, however, fell sharply in 1982 (Table 3).

The major Latin American suppliers of tuna to the U.S. market in 1982 were Panama, Brazil, Venezuela, the Cayman Islands, and Uruguay (Fig. 3). The U.S. has imported tuna from Panama and Venezuela for several years. Brazil has recently begun to develop a tuna fishery, and as a result, the United States began to import significant quantities in 1980. The United States also imports tuna from a few Caribbean countries such as the Cayman Islands, but this tuna is mostly taken by vessels owned and operated by foreigners and only registered there for a variety of tax and legal purposes. The tuna is mostly caught in the eastern Pacific and transhipped in Panama. Uruguay has regularly exported small quantities of tuna for several years. These shipments are largely albacore caught by Asian longline operations based in Montevideo.

The United States imports primarily frozen tuna which is then packed at canneries in southern California and in Puerto Rico. Almost all of the 56,900 t of tuna imported from Latin America in 1982 was shipped frozen (Table 4). The United States imported only negligible quantities of canned tuna from Latin America in 1982, primarily because embargoes were in place on the major Latin American tuna canning countries, Mexico and Ecuador. Several other Latin American countries (Brazil, Costa Rica, and Venezuela) also can tuna, but did not export to the United States in 1982. Brazilian companies, however, are planning a major expansion of their canned tuna production and may in the future enter the U.S. market. Panama and Trinidad are reportedly studying the possibility of building tuna canneries. Frozen tuna enters the United States duty free, while tariff duties, especially the 35 percent duty on tuna canned in oil, have tended to limit imports of canned tuna from Latin America as well as from other exporting countries. Canned tuna exports to the United States, especially from Asian countries, however, have increased in recent years. (Source: IFR-83/51.)

[1] The Peruvian Government has not certified that its fishermen are taking measures to limit the incidental kill of porpoises associated with the yellowfin tuna purse seine fishery. Until the Government submits that certification, exports of yellowfin tuna to the United States continue to be embargoed under the terms of the Marine Mammal Protection Act of 1972.

The Effect of El Niño on Ecuadorean Fisheries

Ecuador is one of the countries most severely impacted by the 1982-83 El Niño phenomenon in the eastern Pacific Ocean. Sea surface temperature anomalies have been particularly severe off its coast. An Ecuadorean Naval Oceanographic Institute (INOCAR) report, describing the genesis and impact of the current El Niño, indicates that the 1982-83 El Niño has not followed the previously established pattern. INOCAR maintains that it has been the most catastrophic visitation of any El Niño on record and the most prolonged. Ecuador's commercial marine fish catches have diminished sharply while on shore, heavy rains have caused widespread flooding and crop damage.

INOCAR believes that the 1982-83 El Niño apparently has developed as a result of an east-west atmospheric imbalance over the entire south Pacific. A high pressure area over Darwin, Australia, in early 1982 began moving eastward to fill a low pressure area over the Tahiti-Easter Islands region. After about 4 months, the first manifestations of El Niño appeared off the northwest coast of South America, especially southern Ecuador and northern Peru. By early January 1983, the sub-oceanic isotherm of 25°C had sunk to a depth of 70-100 m between the Ecuadorean coast and the Galapagos Islands. Surface water temperatures reached 29.5°C. Indigenous fish stocks accustomed to the colder waters of the Humboldt Current dispersed or migrated south and their normal reproductive cycle has been greatly disrupted.

The warm waters off Ecuador caused drastic reductions in the abundance of phytoplankton and diatoms, food sources for the various commercial fish stocks harvested by Ecuadorean fishermen. The country's principal fishery is for thread herring, but catches of that species are well below 1982 levels. Catches of other species, such as mackerel, have also declined. Ecuadorean officials are particularly concerned about mackerel stocks. As a result of the warmer water temperatures associated with El Niño, the mackerel schooled closer to the coast than usual, making them more vulnerable to fishing effort. As a result, Ecuadorean fishermen who were having difficulty locating the thread herring and sardines they usually catch, intensified their effort on mackerel. Mackerel catches began to drop precipitously in December 1982. The fishery is now limited to a few localized areas in the Gulf of Guayaquil, but fishing is reportedly intense in those areas.

INOCAR is concerned not only with the increased fishing effort, but also with the possible impact of the warmer water on the 1983 mackerel spawning season (normally February), which they believe has been disrupted. INOCAR also reports that the reduced quantities of phytoplankton and diatoms, on which the larval fish feed, has increased cannibalistic behavior. INOCAR has detected a substantially reduced abundance of eggs and larvae of most small pelagics (thread herring, sardine, and mackerel) off Ecuador, compared with observations made by INOCAR in 1981. INOCAR biologists believe that this could mean substantially reduced catches for the next several years.

Only oceanic dinoflagellates common to warm waters and shrimp have apparently benefited from the El Niño phenomenon. Due to extremely high rainfalls since September 1982, the increased run-off of the rivers emptying into the Gulf of Guayaquil has provided a great abundance of nutrients. Shrimp fishermen believe that the resulting abundant crop of shrimp larvae will result in a record 1983 shrimp season. The impact on Ecuador's important shrimp culture industry is less clear. The abundant supply of post larvae will help many growers. The widespread flooding, however, has damaged some ponds and made others inaccessible as roads

Ecuador: El Niño Update

Ecuadorean officials are concerned that the 1982-83 El Niño event may continue off their coast for some time. Some observers had predicted in late July and August that the El Niño was beginning to wind down. Weather specialists in Ecuador, however, have reported some indications that the abnormal weather patterns were continuing.

Several factors normally associated with El Niño events reappeared or intensified in early September. Abnormally high tides were reported and the southeasterly trade winds were reasserting themselves somewhat erratically. Heavy rains had also begun again. Unseasonably heavy rains occurred in early September and reportedly intensified by mid-month. James Aycant, Director of Guayas Province Civil Defense, was especially concerned that the onset of the rainy season could accelerate the return of the intertropical covergence zone which caused the heavy rains while hovering over Ecuador early in 1983.

NOAA also reports that, as of mid-August 1983, sea surface temperature anomalies off Ecuador and northern Peru had stabilized at 3°-5° C above normal. Preliminary reports suggest that the area of cooler water west of the Galapagos has not expanded significantly in August. Some observers thought that the projected expansion of this area might gradually reduce the temperature anomalies off the coast of Ecuador and Peru. (Source: IFR-83/105.)

have been washed out. One report suggests that over $10 million in damage has been done to the ponds.

Precipitation during the El Niño phenomenon has greatly exceeded the normal rainfall for the rainy season. In Salinas, January and February rainfall is usually 48.7 mm. In 1983, however, January and February rainfall amounted to a record 589.4 mm. In Guayaquil, March 1983 rainfall was a record of 779.6 mm, the highest rainfall ever registered there for a single month. For the period November 1982-April 1983, total precipitation was 2,636.0 mm compared with the previous record of 1,669.8 mm for the same period during the last severe El Niño of 1972-73. Average air and water temperature, tides, sea level and wave heights, and relative humidity have all registered much higher values than normal.

INOCAR concludes that about the only benefit from the 1982-83 El Niño is that since it has lasted so much longer than previous El Niños, it has afforded the scientific community much more time to study the phenomenon. Also, the fact that this El Niño was not generated in the normal four-phase fashion attributed to other El Niños has raised new questions about the phenomenon's formation. If atmospheric circulation in the southeast Pacific responds in the normal pattern, the southeast air currents should begin pushing the warm inter-tropical zonal air mass further north and the warm waters of El Niño to the west. This will allow the Humboldt Current to resume its normal flow and precipitation to diminish considerably. However, if the southeast winds cannot displace the warm waters of El Niño before those winds lose their force by the end of the year, another serious episode of El Niño could be in the making and once again bring heavy rainfall. INOCAR believes that the great socioeconomic impact which this El Niño has had, not only on Ecuador, but on other eastern Pacific countries, should prompt a more intense study of the phenomena to better understand its generation and predictability. (Source: IFR-83/69.)

El Niño Effects Less Pronounced off Chile

The 1982-83 occurrence of the El Niño phenomenon has had a pronounced effect on weather patterns and fishing conditions along the entire western coast of Latin America. Unlike neighboring Peru, initial reports from Chile in 1983 suggest that Chilean fishermen have so far benefited from the phenomenon. El Niño events are usually characterized by an increase in water temperature, a deepening of the thermocline, changes in wind trends, and abnormal precipitation. Off northern Peru and Ecuador, where the climatic anomalies were most severe, the event was prolonged and has had a significant impact on the local fishing industry.

Off Chile the effects have been less pronounced. One of the primary effects of the warmer water has been on the schooling behavior of the South Pacific sardine[1]. Local observers report that the sardines have formed unusually large schools which enabled fishermen to catch them more easily and to sharply increase landings. During the first half of 1983, sardine landings amounted to 1.6 million metric tons (t), equal to the total Chilean catch of South Pacific sardine in 1981 and only slightly below the total catch in 1982. Although this has been of immediate benefit to the fishermen along Chile's northern coast, the yield is so high that Government officials were concerned about sardine stocks. The full impact of the 1982-83 El Niño thus may not be realized for 3 or 4 years. The long term impact on Chile could be negative if larval or juvenile fish have been affected or if the current large catches reduce the spawning biomass measurably. An immediate adverse impact, however, has been the greater quantity of sardine needed to produce each ton of fishmeal and fish oil. The decline in fish oil yields have been especially sharp, normally 1 t of sardine will produce 0.25 t of fishmeal and 0.06-0.07 t of fish oil, but this year only 0.01-0.02 t of fish oil was being extracted.

The Undersecretariat of Fishing (SERNAP) has taken measures to protect sardine stocks, such as limiting the number of fishing days, establishing a complete prohibition of sardine fishing during spawning, and enforcing various management restrictions. Nevertheless, the government was not willing to institute a complete ban on sardine fishing, and it now appears that the total landings of South Pacific sardine, which reached 1.8 million t in 1982, will exceed 2.0 million t in 1983. Chile's total 1983 catch will probably remain relatively unchanged, however, because during the first half of 1983 there was a drastic drop in the landings of jack mackerel, Chile's second most important fish species. Mackerel stocks apparently migrated north in response to the unusual water and weather conditions.

Biologists participating in research cruises along Chile's northern coast have reported taking tropical species not normally found off Chile, such as ophas, *Lampris reqius*; and Spanish mackerel, *Scomberomorus maculatus*. Some of the fish normally found off northern Chile, such as jack mackerel and black ruff were rarely taken when the effects of the El Niño were most pronounced. Some shellfish species

[1] Sardine has replaced anchovy as Chile's most important species. This trend began in 1971 when another El Niño drastically reduced anchovy stocks.

such as locos and sea urchins also declined. Biologists and fishermen also reported other effects such as large numbers of dead sea lions. Large quantities of seaweed were also reported washed up along the beaches.

Chilean scientists began to report an attenuation of the El Niño event in early 1983, while off Peru, the 1982-83 event did not begin to attenuate significantly until late July. Off Chile, however, temperature anomalies and other climatic abnormalities began to attenuate in February. Biologists at Chile's Instituto Profesional de Iquique in northern Chile, for example, reported that by June, the species normally found off Iquique had begun to return and that it was no longer possible to find large numbers of dead sea lions and seaweed along the beach. (Source: IFR-83/93.)

Potential of Mexican Shrimp Culture High

Mexico is one of the Latin American countries with the greatest potential for shrimp aquaculture. The country already has Latin America's second most important shrimp trawl fishery, after Brazil. Most of the shrimp catch is exported to the United States. In 1982, such shipments totaled over 36,000 metric tons (product weight), worth nearly $375 million. The development of a shrimp culture industry could significantly increase Mexico's shrimp production and export earnings.

Mexico has lagged behind other Latin American countries in developing a shrimp culture industry, however. Shrimp culture in Ecuador, Brazil, Panama, and other countries has been undertaken by private investors, often with technical and financial assistance from United States and other foreign investors. Mexican law, however, reserves several particularly valuable species, such as shrimp, to cooperative fishermen. Private individuals in Mexico have thus been unable to culture shrimp or invest in shrimp culture projects. As a result, the industry in Mexico has lagged behind developments elsewhere in Latin America. Mexico's fishery cooperatives generally lack the technical and financial capabilities to enter the industry without extensive government assistance.

The Mexican Government has assigned a special priority to aquaculture in its fishery development program. As part of this program, the Government has done some research on shrimp culture and has been working with several cooperatives to promote commercial shrimp culture.

The U.S. Consulate in Mazatlan reports that the Mexican Government is currently sponsoring six shrimp culture projects with cooperatives in the Pacific coast State of Sinaloa. The Japanese had previously done some work on shrimp culture during the late 1960's, before the 1972 Fisheries Development Law reserved shrimp exclusively for the cooperatives. The Japanese-owned ponds (about 300 hectares each) were located near Villa Union in southern Sinaloa. Mexican experts believe that these ponds were too large and have recommended building smaller ponds of about 100 hectares each which they believe will be more productive. The projects are being financed by the Mexican Government's Banco Nacional Portuario y Pesquero (Banpesca) and were expected to be completed by October 1983.

One of Banpesca's new shrimp culture projects is located at Marmol and is similar to the other five projects. The Marmol project will cost about 30 million pesos[1] and will provide employment for about 30-35 cooperative members who will repay Banpesca from their earnings. Banpesca believes that the project will produce about 0.5 t of shrimp per hectare of pond, or about 50 t of shrimp per year. The project also includes plans for oyster and fish culture.

Banpesca believes that shrimp culture investments compare favorably with investments in the shrimp trawl fishery. Mexico's Pacific shrimp grounds already are heavily fished. A new trawler costs about 18-30 million pesos, has a useful life of about 10 years, and is crewed by about 5 fishermen who will catch about 10-12 t of shrimp per year. Banpesca believes that its shrimp ponds will employ more people, have longer useful lives, and produce more shrimp per peso invested than equivalent investments in shrimp trawlers.

The Government views the shrimp culture projects as part of its general rural development program. Each of these projects will help create a new rural center. Besides the jobs for the pond workers, transportation and processing facilities for each project will have to be built. The State of Sinaloa is also contributing to the projects by upgrading the roads and by building more schools for the children of the pond workers. New houses and stores will be built to supply not only the pond workers, but the teachers and other employees that the development will produce. Thus each project will provide far more jobs than those of just the pond workers. In addition, each of the projects is in an area away from the major population centers in Sinaloa. Thus, the projects will help to alleviate one of Mexico's major problems, the movement of the rural population to the major urban centers. (Source: IFR-83/76.)

[1]The Mexican peso has fluctuated widely on foreign currency markets since January 1982, but traded at about 150 pesos to the U.S. dollar on the free market in mid-year.

Note: Unless otherwise credited, articles in this section are from either the Foreign Fishery Information Releases (FFIR) compiled by Sunee C. Sonu, Foreign Reporting Branch, Fishery Development Division, Southwest Region, National Marine Fisheries Service, NOAA, Terminal Island, CA 90731, or the International Fishery Releases (IFR), Language Services Biweekly (LSB) reports, or Language Services News Briefs (LSNB) produced by the Office of International Fisheries Affairs, National Marine Fisheries Service, NOAA, Washington, DC 20235.

Circle Hooks Outfish Traditional Halibut Hooks

In recent years, Pacific halibut fishermen have experimented with different types of hooks and reported higher catches with a circle-shaped hook as compared with the traditional J-shaped hook. Although relatively new to the halibut fishery, circle hooks have been used for many years in other fisheries such as the tuna longline fishery, and they appear to share similar characteristics with hooks used by Native American fishermen prior to the 1900's.

To examine the relative efficiency of circle hooks, the International Pacific Halibut Commission (IPHC) chartered the M/V *China B* during July-August 1983. The vessel used snap gear and fished near Sitka, Alaska. The National Marine Fisheries Service played a key role in the study by providing a two-man submersible with a support vessel to observe the hooks along the bottom. Results from the submersible were not yet available, but should provide additional information on the fishing characteristics of the two types of hooks.

Two experimental designs were used in the study. The first involved alternating each hook type (i.e., a circle hook followed by a traditional hook, etc.). The second design called for alternating the hook type on every skate.

The results (Table 1) clearly indicate that circle hooks outfished traditional halibut hooks: Circle hooks caught 39 and 61 percent more poundage in the two experiments. Circle hooks tended to catch slightly smaller halibut than the traditional hook, although more observations are needed to confirm this difference.

The use of circle hooks contributed to the high catch rates observed in the 1983 halibut fishery which in turn resulted in taking the catch limit in fewer days than expected. The use of circle hooks also presents a problem in standardizing data collected from the commercial fishery for stock assessment purposes. Consequently, IPHC needs more information on the fishing characteristics of circle hooks. Additional experiments were planned later in 1983 or early 1984 to determine more precisely the differences in hook efficiency and to relate those differences to factors such as soak time, levels of abundance, and size of fish. (Source: IPHC.)

Table 1. — Halibut hook experiment results.

	Alternate hook experiment			Alternate skate experiment		
	No. of hooks	Halibut/100 hooks		No. of hooks	Halibut/100 hooks	
Hook type	observed	No. of fish	Pounds	observed	No. of fish	Pounds
Circle hooks	1,410	24.9	647	991	30.0	768
Traditional hooks	1,388	16.3	466	1,122	17.7	478

Pacific Halibut Take Exceeds 1983 Limits

The 1983 fishery for Pacific halibut closed 21 September with the final closure of Area 4B (the Aleutian chain west of long. 172° W), with preliminary data showing the harvest about 7 million pounds over the catch limit. The fishery will remain closed until reopened in 1984.

Preliminary catch figures compiled by the International Pacific Halibut Commission show that the catch during the final opening in Area 4B was 1.1 million pounds. The total catch for the area was 1.3 million pounds, well above the catch limit of 800,000 pounds.

The total halibut catch for the 1983 season, based on preliminary figures, was 37.6 million pounds, substantially above the 30.6 million pound catch limit. A summary of the catch limits and total catch for the nine regulatory areas is given in Table 1.

The excessive catch in four of the nine regulatory areas is attributed to substantially more fishing effort than was anticipated by the Commission, and by increases in the catch per unit of effort (CPUE), particularly in Alaskan waters. Some of the increase in CPUE can be attributed to increased use of circle hooks by halibut fishermen, and some is likely due to further increase in halibut abundance.

Table 1. — Preliminary 1983 harvest data for Pacific halibut.

Regulatory area	Catch limit (10^6 lb)	Total catch (10^6 lb)
2A	0.2	0.2
2B	5.4	5.4
2C	3.4	6.2
3A	14.0	14.0
3B	5.0	7.4
4A	1.2	2.5
4B	0.8	1.3
4C	0.4	0.4
4D	0.2	0.2
Total	30.6	37.6

Texas' Wilson Hatchery Produces Red Drum Crop

The Texas Parks and Wildlife Department's new John Wilson Hatchery at Flour Bluff produced its second crop of red drum with 1.8 million fingerling-sized fish stocked in Nueces Bay in late September. Gene McCarty, biologist in charge, said the 1- to 3-inch fish were

released at two locations in the bay in the northeast corner of the Corpus Christi Bay system. The first group of red drum spawned at the saltwater hatchery during May produced 2.4 million fingerlings which were placed in Espiritu Santo Bay near Port O'Connor in June.

Hatchery personnel induce mature red drum to spawn in indoor tanks, manipulating light and water temperatures to simulate the fishes' spawning season. McCarty said he is optimistic that bay stockings will revive the fishery in Texas bays, since net surveys at Espiritu Santo Bay indicate the stocked fish are enjoying good survival and growth rates. He added that the new fingerling class was hardly in the water before the same 12 brood fish began another spawn. This new batch of fingerlings would be ready for harvest from the ponds and release into the wild by around 3 November, McCarty said. The Wilson hatchery, billed as the only one of its kind in the world, was constructed with funds raised by the Gulf Coast Conservation Association and built on land donated by Central Power and Light Co. of Corpus Christi.

Texas Boasts Record Production Year for Striped, Hybrid Basses

Production of striped bass and striped-white bass hybrids reached an all-time high during 1983, according to Texas Parks and Wildlife Department officials. Three hatcheries were involved in the year's output of 1.5 million stripers and 2.5 million hybrid fingerlings for stocking across the state.

Regional Fish Culturist Charles Gray of Fort Worth said the 4 million-plus fish not only were the best crop in terms of numbers, but the fish were the healthiest ever shipped out of the hatcheries. "We have developed improved methods for fertilizing our rearing ponds to assure that maximum numbers of zooplankton are available when the ponds are stocked with fry," Gray explained. "If the fry are fed well and healthy in the ponds they will have better survival rates in the lakes when stocked as fingerlings." Hatchery workers treat the rearing ponds with inorganic phosphoric acid and ammonium nitrate as well as organic materials such as cottonseed meal.

The fish are produced by using wild brood fish from which eggs and milt are stripped by hand. The fertilized eggs are kept in aquaria for 5 days until they develop the ability to swim, then are placed in the rearing ponds. Gray commented that even better production may be possible in the future because of recent advancements in fungus and bacteria control used during the critical five-day period when the newly hatched fry are in the containers.

Striped bass are anadromous, live in salt water, and swim up freshwater rivers to spawn. However, they are able to survive in freshwater impoundments and in some cases can reproduce if sufficient flowing water is present. Hybrid stripers are nonreproducing fish which usually are stocked in smaller impoundments, notably power-plant-heated reservoirs.

Washington Razor Clams and Season "Disappear"

Washington Department of Fisheries Director Bill Wilkerson signed an emergency order late last summer that indefinitely postponed the razor clam season on coastal beaches. The action followed a Department discovery in early September that two-thirds (13.5 million) of the razor clam population could not be found.

When the spring digging season expired on 15 June, the Department estimated the razor clam population at slightly over 20 million. But later test digs suggested the population had dropped to 6.5 million razor clams. Following this discovery, the Department met with the public in Ilwaco and Aberdeen to review the razor clam resource status.

"We cannot afford to open the season when we have apparently lost two-thirds of a natural resource," Wilkerson said. "Our shellfish management staff has begun an investigation on this strange phenomenon. Hopefully, we can determine an answer to the problem. At that point, we will be in a much better position to consider a razor clam season."

Initial reports indicated the problem was caused by a new microscopic parasite, previously unknown to science, which causes a respiratory ailment in the razor clams. (Source: Washington Department of Fisheries.)

Texas Biologists Cross Redfish and Black Drum

Biologists at the Texas Parks and Wildlife Department's Marine Fisheries Research Station in Palacios have successfully produced a hybrid cross between the red drum (redfish) and black drum. They hope the hybrid will prove to be a hardy, fast-growing sport fish.

About 500,000 fertilized eggs were produced by a female black drum and a male redfish earlier in 1983. The resulting fry were placed in ponds until they reached about 1½ inches in length, and then were stocked experimentally in Lake Creek Reservoir near Waco. Nick Carter, inland fisheries research coordinator in Austin, said although subsequent netting surveys failed to retrieve any of the hybrids, he believes the fish may have gone into deep water areas out of the reach of nets. "We are fairly optimistic about the hybrid drum because they are easy to produce and appear to have high egg fertilization and survival rates," Carter noted. "The fish we stocked in Lake Creek appeared to be in excellent shape."

Carter said the hybrid more closely resembles the popular redfish in appearance, but it is deeper-bodied like the black drum. It is mottled black and silver in color, lacks the characteristic black tail spot seen on redfish, and also has lost the black vertical bars of the black drum.

There are several reasons for optimism about the future of hybrid drum as a freshwater sport fish. Stocking of saltwater redfish already has proven successful in certain reservoirs where the water chemistry is favorable. Also, hybrid crosses of striped and white bass have shown their worth as sport fish in scores of Texas lakes. "There is much yet to be learned about the hybrid drum, since it is a new fish," Carter said. "However, if they survive and grow as well as we think they can, they have excellent sport fish potential."

New NMFS Scientific Reports Published

The publications listed below may be obtained from either the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402; from the Publications Services Branch (E/AI13), National Environmental Satellite, Data, and Information Service, NOAA, U.S. Department of Commerce, 3300 Whitehaven St., Washington, DC 20235; or from the National Technical Information Service, Springfield, VA 22151. Writing to the agency prior to ordering is advisable to determine availability and price, where appropriate (prices may change and prepayment is required).

NOAA Technical Report NMFS SSRF-769. Kaylor, John D., and Robert J. Learson. **"Krill and its utilization: A review."** July 1983, 10 p.

ABSTRACT

This article is based on a review of the literature on 1) the Antarctic krill resource, 2) multinational efforts to use krill as food, and 3) technological, economic, and marketing aspects of krill. The decimation of baleen whales, significant krill predators, has brought about an apparent overabundance of this protein-rich crustacean. Since the krill biomass exceeds the world's annual tonnage of fishery products, a close examination of the potential of krill stocks is justified.

Krill is an extremely rich source of protein and fat, and there is the potential of valuable byproducts such as chitin and chitosan. However, the harvesting operation may prove to be one of somewhat low economic return. The technology of using krill to form various food products acceptable to western preferences is not yet well developed. Utilization technology seriously lags behind harvesting technology.

Finding the potential value of krill requires an appraisal of 1) feasibility of producing krill products with a reasonable degree of marketing acceptability, 2) the value of our lending technical assistance to some nation to achieve the above, and 3) the economic and international pressures that are likely to favor those nations that are already completely subsidized and have vertical integration of their fisheries.

It is widely believed that abundant, protein-rich krill could contribute substantially to the world protein food supplies. Owing to the lack of development of a krill product possessing wide appeal and the unknown economic return of this potential fishery, eventual success seems dependent on government-subsidized operations.

NOAA Technical Report NMFS SSRF-770. Keser, Milan, Donald F. Landers, Jr., and Jeffrey D. Morris. **"Population characteristics of the American lobster, *Homarus ameri-***

The Fishes of the Gulf of Mexico

Number one in the W. L. Moody, Jr., Natural History Series of the Texas A&M University Press is **"Fishes of the Gulf of Mexico,"** subtitled "Texas, Louisiana, and Adjacent Waters," by H. Dickson Hoese and Richard H. Moore. The authors are, respectively, professor of biology at the University of Southwestern Louisiana and assistant professor of biology at Coastal Carolina College.

With over 600 photographs and drawings, more than half in full color, the volume pictures nearly 500 species of fish found in Gulf waters along the Texas-Louisiana coast. Complementing them is a detailed description of each fish, with common and scientific names, identifying characteristics, abundance, importance, habitat, geographic range, and approximate maximum size. Also included are temperate, subtropical, and tropical species which the authors believe are most likely to also be found in this region.

Introductory chapters review the ecology and zoogeography of the Gulf and outline conservation work, with a short history of ichthyological research in the area. An illustrated glossary defines technical terms and appendices list several offshore and deep-water species which may stray onto the continental shelf, freshwater fishes that may be washed into the Gulf, French (Cajun) and Spanish (Mexican) common names of some species, and more. An extensive bibliography lists both general and specific references. The volume also includes many excellent underwater fish photographs by Farley Sonnier and drawings by Dinah Bowman.

Drawing on previous works, the authors have devised easy-to-use keys to the families and species and attempted to verify each species which had been reported for the area. Well written, illustrated, and produced, this thorough volume should be of interest and value to commercial and sport fishermen, biologists, and others interested in the marine life of the northwestern Gulf. The 327-page volume is available from the Texas A&M University Press, Drawer C, College Station, TX 77843 for $9.95 (paper) and $14.95 (cloth) plus $1.00 postage.

A Guide to North American Sharks

Number five in the W. L. Moody, Jr., Natural History Series, **"The Sharks of North American Waters"** by Jose I. Castro, has been published by the Texas A&M University Press, Drawer C, College Station, TX 77843. The author, currently studying shark reproduction and fetal-maternal relationships, has written 108 species accounts for all sharks reported within 500 n.mi. of the United States and Canada from the Atlantic Ocean to lat. 20°N. Data is also given for a few deep-water species from adjacent areas which might possibly stray into North American waters.

The first part of the book provides brief, general accounts of the sharks: Their evolution, anatomy, reproduction,

***canus*, in eastern Long Island Sound, Connecticut."** October 1983, 7 p.

ABSTRACT

Population characteristics of the American lobster have been studied extensively in the vicinity of Millstone Point, Conn. Since 1975, 22,150 lobsters have been tagged, and pertinent biological data recorded. Catch per unit effort was similar among years, but was significantly higher for wire than wood pots. Legal-sized individuals ranged from 4.5 to 18.1 percent of the total catch. The percentage of culled lobsters ranged from 9.7 to 17.4 percent, and was greater for wood than wire pots. The sampled population was comprised of 51 percent males and 49 percent females. Berried females accounted for 3.1-6.7 percent of the total catch, and over half of these were of sublegal size. Growth per molt averaged 13.0 percent and was not significantly different between sexes. A major period of molting occurred in the late spring and early summer.

NOAA Technical Report NMFS SSRF-771. Smolowitz, Ronald Joel. **"Mesh size and the New England groundfishery — applications and implications."** July 1983, 60 p.

ABSTRACT

Mesh size control has been advocated from the earliest days of the otter trawl fishery in the United States. Researchers determined that larger meshes in the cod end of a trawl reduce discarding by allowing small fish to escape; a process known as size-selection. This selectivity is measured by the selection factor — the relationship between the 50 percent retention length and the stretched length of the mesh. Selection factors vary by species, net material, duration of tow, speed of tow, size of catch, and with variations in mesh size.

Cod-end mesh size experiments were conducted aboard eight New England otter trawlers from December 1977 to October 1978 to examine the possible effects of increasing the mesh size in that fishery. Selection factors were determined for Atlantic cod, *Gadus morhua* (3.33-3.80), haddock, *Melanogrammus aeglefinus* (3.04-3.47), yellowtail flounder, *Limanda ferruginea* (2.16-2.29), pollock, *Pollachius virens* (3.26-3.33), winter flounder, *Pseudopleuronectes americanus* (2.04-2.27), and American plaice, *Hippoglossoides platessoides* (2.25-2.41). For Atlantic cod, haddock, and winter flounder, there was a reduction of discards, up to 93 percent, and an increase in landings, by as much as 44 percent, with the larger mesh (133-138 mm). For yellowtail flounder, there was a reduction of discards and of landings.

Mesh size regulation as a management tool first requires the determination of the objectives in order to choose the size mesh. Enforcement difficulty, especially in the New England mixed fishery, is the greatest obstacle to overcome. The implications of mesh management reach beyond the fishery into the processing and financial sectors of the industry.

NOAA Technical Report NMFS SSRF-772. Squire, James L., Jr., and Daphne V. Nielsen. **"Results of a tagging program to determine migration rates and patterns for black marlin, *Makaira indica*, in the southwest Pacific Ocean."** July 1983, 19 p.

ABSTRACT

Marine game fish anglers reported tagging a total of 2,576 black marlin, *Makaira indica*, from 1968 through 1978 near the Great Barrier Reef, north Queensland, Australia, as part of the National Marine Fisheries Service Cooperative Marine Game Fish Tagging Program — Pacific Area. Sixty tagged black marlin were recaptured during an 11-year period for a recapture rate

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migration, distribution, fishing techniques, utilization, and attacks on humans. A key to the shark families then leads into the second part: Family and species descriptions. This includes descriptions of each family, identification keys for each species, species accounts, and illustrations of each species. The keys employ such readily observable external features as shape, proportion, color, shape of teeth, and geographic range.

Though a few species accounts are necessarily brief because little about them is known, most others supply essential details on the description, range, biology, reproduction, relationship to man (commercial uses, economic losses, danger, and recreational or scientific values), how caught, and selected references. Each shark covered is illustrated in profile plus a snout outline and upper and lower teeth outlines. Besides the many line drawings, the book is illustrated with 17 excellent underwater photographs of live specimens. A short appendix includes data on the goblin shark, a primitive deep-water species, and the megamouth shark taken in 1976 off Oahu, Hawaii.

Interest in sharks has grown in recent years and many scientists, anglers, commercial fishermen and others will no doubt find this well written and illustrated book a handy and useful field guide and reference. Indexed and with a good bibliography, the 180-page volume is available from the publisher for $19.50 (cloth) and $9.95 (paper) plus $1.00 postage.

Fisheries Ecology and Management

A new fisheries reference and textbook, **"Fisheries Ecology,"** by Tony J. Pitcher and Paul J. B. Hart, has been published by Avi Publishing Company, 250 Post Road East, P.O. Box 831, Westport, CT 06881. The authors are, respectively, Lecturer in Zoology at the University College of North Wales and Lecturer in Zoology at the University of Leicester.

Concerned with the ecology of exploited fish populations, the volume provides a broad view of the subject, dealing in large part with marine fisheries, but including applicable aspects of freshwater fisheries. Aimed at advanced students of fisheries, aquaculture, and marine ecology, the book's eleven chapters give a thorough overview of fishes, fisheries, fisheries managment, economics, and fish nutrition, growth, production, and recruitment.

Chapter 1 provides basics on the structure and senses of fishes, their biology, and adaptations to a variety of aquatic communities. Chapter 2 discusses the growth of the world fisheries since 1945, future fish supplies, fishing methods and fleets, and the storage and handling properties of fish. The biological basis of the fisheries is explored in chapter 3 — stock concepts, fish abundance and its estimation, and population age structure, mortality schedules, and fecundity. Chapter 4 examines fish nutrition,

of 2.3 percent. Average weight of black marlin tagged was estimated to be 175 kg (385 pounds). Anglers tend to overestimate weight at time of tagging and short-term recaptures (0-60 days) indicate an average angler overestimate of 16 kg (35 pounds) per marlin.

Sex was determined for 28 recaptures; 25 (89 percent) were reported as males and 3 (11 percent) reported as females. Average weight of males at recapture was 91 kg (195 pounds), for females, 221 kg (488 pounds).

Vector analysis of time, distance, and direction data for tag recovery locations indicated migration direction (vector mean bearing) and distance (vector mean distance from point of tagging) by periods of release time: 0-60 days, 121°/72 n.mi., 61-120 days, 134°/446 n.mi., 121-240 days, 097°/1,256 n.mi.

The greatest distance (2,100 n.mi.) recorded from the point of tagging was for a black marlin recaptured northeast of New Zealand, 235 days after tagging. Black marlin tagged early in the north Queensland fishing season (September) tended to migrate away from the area of tagging at a lower rate for the first 0-60 day period than black marlin tagged in October, November, or later in the fishing season.

Tag recoveries were made near the tagging location 1, 2, and 4 years after tagging. Locations of recapture for these black marlin were calculated to be a vector mean distance of 58.3 n.mi. from the point of tagging. Longline high catch rate areas for black marlin indicate a monthly movement for the first 240 days of release time not unlike that observed by tagging. In the summer the centers of high catch rate show a south to southeast movement off the east coast of Australia from the tagging area, then a northward movement in the winter and spring to the New Guinea-Bismark Archipelago-Solomon Islands area. The amount of interchange with the Indo-Pacific and areas to the north is unclear, although emigration from the tagging area to north of New Guinea was recorded.

NOAA Technical Report NMFS SSRF-774. Judy, Mayo H., and Robert M. Lewis. **"Distribution of eggs and larvae of Atlantic menhaden, *Brevoortia tyrannus*, along the Atlantic coast of the United States."** October 1983, 23 p.

ABSTRACT

Atlantic menhaden, *Brevoortia tyrannus*, eggs and/or larvae were collected during 52 of 77 ocean cruises by 12 vessels from 1953 to 1975. The combined cruises extended from the Antilles Current southeast of Florida to Cape Cod, Mass. Eggs and/or larvae were present in samples from Cape Canaveral, Fla., to Martha's Vineyard, Mass. Eggs were found at several locations off the coast from October to February and they occurred in the upper water column (10 m or less in depth). The largest batch of eggs were caught in December off North Carolina. Larvae were found at numerous locations off the coast and catch by gear indicated that they appear to be most concentrated in the upper portion of the water column. Larvae were caught each month except September. They were more concentrated in the South Atlantic Bight than north of Cape Hatteras, N.C. Most larvae were taken between 20 and 75 km from shore and the two largest catches occurred in December and March off North Carolina. The cruise data show that the seasonal distribution and abundance of eggs and larvae coincide with the seasonal distribution of adults.

NOAA Technical Report NMFS SSRF-775. Fogarty, Michael J. (editor). **"Distribution and relative abundance of American lobster, *Homarus americanus*, larvae: New England investigations during 1974-79."** September 1983, 64 p. (11 papers.)

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growth, and the dynamics of a fish population, and chapter 5 briefly outlines the evolutionary effects of mortality on fish populations.

Chapters 6 and 7 discuss recruitment and prediction of fishery yields (surplus yield models), and chapter 8 presents dynamic pool models and fishery management. Chapter 9 discusses how economic factors influence fishery management while chapter 10 reviews general principles of fish farming (salmon, milkfish, carp, etc.) and its improvement. The final chapter reviews some of the problems and progress in managing various fisheries and discusses contemporary fishery problems. Cohort analysis is described in an appendix.

Broader than some other texts, the volume considers fish as part of the total ecosystem and is enhanced by use of examples from a wide variety of marine fisheries worldwide. It outlines the processes to be identified, described, measured, analyzed and predicted to manage fisheries, and, in sum, is a good synthesis of fisheries biology, ecology, harvesting, economics, and fisheries management.

The volume provides a list of references plus an index of fish names and a general index. The 414-page hardbound volume is available from the publisher for $32.50 in the United States and $36 elsewhere in North and South America.

Fisheries and Fish Technology

"Fish Handling & Processing," edited by A. Aitken, I. M. Mackie, J. H. Merritt, and M. L. Windsor, is the second edition of the 1965 volume of the same title produced by the Torry Research Station in Aberdeen, Scotland. The new edition is considerably updated and revised and, receiving special attention is chilled-water storage of fish and freezing fish at sea, both scarcely mentioned in the first volume. Also, making frozen fillet blocks is dealt with in some detail.

This book begins with some basic facts about fish and what happens to them after capture. Chapters 4 and 5 then outline the handling of fish at sea and on shore, respectively. Subsequent chapters relate modern techniques of freezing, cold storage, freezing at sea, thawing fish, smoking and canning fish, handling and processing shellfish, and "other" products (i.e., minced fish, fish blocks and cakes, pastes, spreads, pates, marinades, etc.), fish byproducts (i.e., fish meal, silage, oils, FPC's, etc.), hygiene, and quality assessment and quality control.

Well illustrated, the book provides a well-rounded, easily readable account of the theory and practice of fish handling and processing. While the fishing industry and practices in nations other than England are not mentioned, the book does provide good and sound information with wide applicability.

Indexed, the 192-page hardbound volume is available from Her Majesty's Stationery Office, 49 High Holborn, London WC1V 6HB England for £10.

"Proceedings of the Seventh An-

Climatological Atlas of the World Ocean

The National Oceanographic Data Center (NODC) has announced the availability of digital data tapes containing data drom the "Climatological Atlas of the World Ocean" (NOAA Prof. Pap. 13). The atlas represents the published results of a project to provide researchers with objectively analyzed, gridded fields of major oceanographic variables. Data analysis and compilation of the atlas was carried out by Sydney Levitus of the NOAA's Geophysical Fluid Dynamics Laboratory.

The atlas and data tapes present a synthesis of all temperature, salinity, and oxygen data available from NODC's Oceanographic Station Data, Mechanical Bathythermograph, and Expendable Bathythermograph files. The data have been analyzed in a consistent, objective manner at standard oceanographic depth levels on a one-degree latitude-longitude grid between the surface and ocean bottom with a maximum depth of 5,500 m. The data tapes described in this brochure contain annual summaries of temperature, salinity, dissolved oxygen, and percent oxygen saturation and seasonal summaries of temperature and salinity.

These analyses are intended primarily for use in the study of the role of the oceans in controlling the earth's climate, but they can also be used for other scientific investigations. Preliminary results have already been used in a variety of ways ranging from diagnostic studies of the role of the oceans in the global heat balance to computations of the general circulation of the Atlantic Ocean.

Copies of the annual analyses (temperature, salinity, dissolved oxygen, percent oxygen saturation) and seasonal analyses (temperature and salinity only) from the "Climatological Atlas of the World Ocean" are available from the NODC on magnetic tape. These data constitute NODC Accession No. 83000073. Magnetic tape characteristics are: 9 track, 1600 BPI, fixed block, record length = 80 bytes, 50 records (4,000 bytes) per physical block. The short unpacking program used to read the tapes is included as the first file on each tape.

Cost of the tapes (subject to change without notice) is as follows: Individual tapes (please specify), $110; annual analyses (2 tapes), $220; seasonal analyses (4 tapes), $440; and annual and seasonal analyses (6 tapes), $660.

Orders for digital data tapes should be directed to: National Oceanographic Data Center, User Services Branch, NOAA/NESDIS E/OC21, Washington, DC 20235. Telephone: 202-634-7500 (commercial) or FTS 634-7500. Please make check or money order payable to "Department of Commerce/NOAA/NODC." All payments must be in U.S. Dollars and drawn on a bank located in the United States. Bound paper copies of the "Climatological Atlas of the World Ocean" (NOAA Professional Paper No. 13) are available at $11.00 each from: Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. When ordering refer to Stock No. 003-017-00509-7.

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nual Tropical and Subtropical Fisheries Technological Conference of the Americas," compiled by Ranzell Nickelson II, has been published by the Sea Grant Program, Texas A&M University, College Station, TX 77843. The volume provides 38 articles, edited by their respective authors, on a wide variety of topics including shark longlining, handling, and quality; verifying "freshness" of tournament-caught fish, edibility characteristics and chemical composition of 16 southeastern U.S. marine fishes; retort pouch processing, minced turbot and pollock patties, and more.

Papers are presented on *Vibrio cholerae* and seafoods, bacteriology of fresh and spoiling tropical fish, hydrocarbon analysis of shrimp from oil polluted waters, biological treatment of fish processing wastes in the tropics, TMA formation in dried fish, controlled atmosphere packaging of swordfish steaks, shrimp stored in vacuum and atmospheres containing CO_2, islolation of organisms of public health significance from clams and oysters, and packaging and microbiology of seafoods in transit. Also discussed are FAO fish utilization programs in Latin America, trends in export of Federally inspected fish, FAO marketing information and advisory services for fish products, and optimized drying conditions for stockfish produced from underutilized species.

The 391-page volume paperbound presents a wide variety of articles and progress reports for food technologists interested in the unique problems of production, processing, packaging, distribution, and utilization of tropical and subtropical fish species, and is available from the publisher for $10.

POLAND PUBLISHES FISH ENCYCLOPEDIA

Publication of **"Encyklopedia ryb Morskich"** (Encyclopedia of Marine Fishes), by Stanislaw Rutkowicz, has been announced by the Polish Maritime News. Publisher is Wydawnictwo Morskie, Maritime Publishers of Gdansk, ul.Szeroka 38/40, 80-835 Gdansk, Poland. The author, a former FAO biologist, was a senior scientist at the Department of Ichthyology of MIR, Sea Fisheries Institute, Gdynia.

The large volume contains descriptions and color illustrations of 1,000 important marine species from the Atlantic, Pacific, and Indian Oceans. Selected for inclusion were those species commercially or recreationally valuable as well as numerous aquarium fishes. Some other species were included for taxonomic or systematic reasons.

Introductory chapters present data on morphology, anatomy, structure and senses of fishes and the biology and ecology of fish. The systematic listing of fish is based on the 1970 FAO "Taxonomic classification," and lists 97 orders and about 450 families of marine and freshwater fishes. An illustrated taxonomic key is given to about 100 orders and 250 families. Each species account presents the scientific name and common names in several primary languages. Opposite the picture is data on

size, morphology, biology, ecology, importance, and catches, along with symbols indicating common fishing techniques (i.e., trawl, seine, etc.), uses (canned, frozen, etc.), and a chart illustrating distributional range.

Useful indexes are provided to scientific names and common names in English, Russian, Polish, German, Spanish, French, etc. Species are also indexed by FAO Statistical grid areas. The 660-page hardbound book is available from the publisher for Zl4000. The Polish-language volume is aimed at an audience of fishermen, fisheries students, and natural history schools, etc. It will be most useful to those with Polish language skills, although the species accounts, distribution maps, and use of symbols provide much data for other readers.

Fish Feeding Habits, Predation, and Behavior

"Gutshop '81 Fish Food Habits Studies," published by Washington Sea Grant, 3716 Brooklyn Ave. N.E., Seattle, WA 98105 presents the proceedings of the third such Pacific workshop. Editors are Gregor Cailliet and Charles Simenstad.

The workshop and volume were divided into five topics: Methodology and Statistical Analysis, Bioenergetics of Fish Feeding (i.e. bioenergetics of optimal foraging; trophic transfer of nonassimilated energy from fishes; and bioenergetic effects of feeding activity upon growth and metabolism), Competition and Resource Partitioning, Feeding Behavior of Fishes and Prey, and Fish Feeding as a Structuring Force on Prey Communities.

The first two workshops (1976 and 1978) brought together scientists involved in studies of food habits, predation, feeding behavior, competition and food web structure to achieve some consensus on sampling design and techniques, analysis and statistical procedures, and interpretive tools for fish food habits studies. Thus, the third workshop was more concerned with interpretive concerns with contributors getting into testing of hypotheses regarding ecological concepts involving predation and feeding behavior, and into the role of feeding ecology in the population dynamics of exploited fish populations.

Much broader than the previous workshops, "Gutshop '81" presentations touched upon almost all the major habitats of fishes from at least 22 families. Topics included: Statistics and presentation of results, benefits and constraints upon laboratory and microcosm feeding experiments, sampling problems, mathematical and conceptual models of predator-prey interactions, bioenergetic experiments and models, competition and partitioning of prey resources, feeding behavior, and predation effects upon the structure and abundance of prey assemblages.

The volume is available from the publisher (make checks payable to "University of Washington") for $8. Copies of "Gutshop '78" are also available at $5 while the first, "Fish Food Habits '76" is available from NTIS, Springfield, VA 22151, Order No. PB281819 AS for $13.50 (paper) and $3.50 (microfiche).

State and National Record Fishes Listed

The **"Sportsmans Book of U.S. Records,"** published annually by compiler Joseph Glogan, contains several sections on fish and angling records of interest to sportsmen and those involved in recreational fisheries. The volume differs from other records compilations by listing records for each state plus U.S. national records, and it is a quick and handy source of data on the largest fishes caught by anglers. Species weight records are given state-by-state as well as a table of national records. Separate listings are provided for the heaviest fresh- and saltwater fishes taken on various line classes, fly line leader records, tippets, plus a variety of miscellaneous records or oddities of fishing tackle or other fish catches.

As the title suggests, other sportsmen's records are also included related to hunting, shooting, etc. Thus, the pocketsized paperbound volume is a concise and comprehensive source of records data. The first four editions (1980, 1981, 1982, and 1983) are available from: Sportsmans Book of U.S. Records, 328 East Main Street, Rochester, NY 14604 for $4.95 (plus 75 cents postage) each.

Some Invertebrates and Fishes of Baja California

Publication of **"Marine Animals of Baja California,"** subtitled "A Guide to the Common Fish and Invertebrates," by Daniel W. Gotshall, has been announced by Sea Challengers, 1851 Don Avenue, Los Osos, CA 93402. The volume provides brief descriptions and photographs of 125 species of fish and 62 species of invertebrates commonly encountered in the shallow waters of Baja California.

Text is spare, but includes data on common and scientific names, maximum known size of each species, one or two identifying characters to look for underwater. Most of the photographs — all of live specimens — are excellent and were taken along both peninsula coasts, and out to 250 miles southwest of Cabo San Lucas to the Islas Revillagigedos. Juvenile specimens and both male and female, are shown for several species to facilitate identification.

To identify fishes, readers are advised to study the photographs before diving and to use a "pictorial key" to fish and invertebrate families — line drawings of a representative species of the families shown in the book. In all, 43 fish families are illustrated; invertebrates shown include sponges, hydroids, anemones, gorgonians, sea stars and urchins, sea cucumbers, snails, polychaetes, and more.

To avoid duplication, the author omitted some of the species (covered in his earlier books on Pacific Coast inshore fishes and subtidal marine invertebrates) whose southern range extends down the west coast of the peninsula. Also excluded were such tiny fishes as gobies, tube blennies, and clingfish which often are hidden from view or difficult to identify underwater.

The 112-page volume is a handy reference for the underwater naturalist and is available from the publisher for $17.95 (paperbound) or $29.95 (hardbound, 200 only). A brief bibliography and index is included.

Index, 1983

Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 6, "A List of Common and Scientific Names of Fishes from the United States and Canada," third edition, 1970. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Citations

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lower-case alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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